12-2018

Integration of Educational Technology for the Purposes of Differentiated Instruction in Secondary STEM Education

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I am submitting herewith a dissertation written by Olivia Nichole Ritter entitled "Integration of Educational Technology for the Purposes of Differentiated Instruction in Secondary STEM Education." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

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Integration of Educational Technology for the Purposes of

Differentiated Instruction in Secondary STEM Education

A Dissertation Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Olivia Nichole Ritter

December 2018

Dedication

This project is dedicated to my mother, Denise Hill. I have always worked to make you proud, even though I know in my heart you are proud of me no matter what. Although I blame you for my sometimes-grandiose self-confidence that often causes me to jump into things and find that I may be in a bit over my head, I love you for always being my rock and biggest fan and for truly believing that I can do anything I put my mind to. You are the strongest woman I know, and the greatest fortune in my life is having you as my mother.

Acknowledgements

The decision to step back into the research world as a student once again was a difficult one for me, and earning a doctorate degree proved to be quite the formidable challenge. During my journey through this program, I experienced countless victories and hurdles in every aspect of my life – academic, professional, and personal. There is a saying that it takes a village to raise a child, and I feel like it may have taken a village to help me achieve my goal of earning a PhD. I will never be able to fully express my appreciation and gratitude for my "village," but I will try my best to acknowledge and thank those people now.

I would like to acknowledge the contributions of my dissertation committee who provided the mentorship and support that was needed for me to develop the knowledge, skills, and perseverance to conduct this research and write this dissertation. Dr. Mehmet Aydeniz, my advisor and committee chair, provided me with advice and constructive criticism as I worked to complete this program. He always had my best interests at heart, and, because of this experience, I truly feel I am a better researcher and educator. I would also like to thank Dr. Ashlee Anderson, who was the first to truly introduce me to the world of qualitative research. She helped me – a self-proclaimed believer in numbers and "hard science" facts – see the significance of qualitative study and the important role it would have to play in my future research interests. Furthermore, when I doubted my own abilities as a researcher and doctoral student, Dr. Anderson encouraged me and gave me confirmation that I was capable of surviving and thriving in this program. Dr. Jo Ann Cady provided both mentoring and valuable perspectives about my research interests, as well as future professional endeavors; I am grateful for her honesty and support during this experience. Dr. Yamagata-Lynch introduced me to Cultural-Historical Activity Theory (CHAT), as well as numerous technologies that helped make my life much easier during work on my

comprehensive exams, prospectus, and dissertation. She also offered advice and support as I talked in circles and tried to navigate the complexities of CHAT and educational research. Without her expertise and guidance, I would still be staring at my computer contemplating the classifications of budgets as opposed to grants within an activity system.

Throughout this doctoral program, I have also worked full-time as a high school teacher. At times, I felt a bit overextended, but I also found a level of support and love from my co-workers that I had no idea could even exist. I would need to write an entire book to truly describe the impact each of these amazing people has had in my life over the past few years, but, for now, I would just like to say I am forever grateful for your kindness and for believing in me even when I did not believe in myself. Thank you, Becky, Brooke, Colleen, Jenni, Jessica, Julie, Kim, Leslie, Nancy, Sam, Shauna, Shawn, Tony, and every single member of my Alcoa family. You are so much more than colleagues; I am extremely fortunate to have each of you in my life and to get to work with you each day. I would also like to thank my students, past and present, who ensure that no class is ever boring and inspire me with their spirit and creativity every day.

I have also been deeply inspired by my peers at the University of Tennessee. Brooke Bianchi-Pennington, my fellow Halls graduate, thank you for always being willing to give me feedback on ideas and talk through issues I encountered throughout my research and dissertation writing process. Dr. Kelly Bailes Wallace, although we did not have many courses together during this program, we turned out to be connected in so many ways. Thank you for lending an ear and a shoulder and for offering your wisdom, valuable perspectives, and support when I needed them most.

I must now speak to Chris and Amelia, my science education scholars. Dr. Christopher Bowen was our science education doctoral pioneer, leading the way for Amelia and me. Your positivity and passion for teaching are infectious, and you never let me get too discouraged by things that were happening in the various facets of my life. You always reassured me that there was light at the end of the tunnel and that the light was indeed sunshine and not a train. My doctoral program experience also introduced me to the amazing Dr. Amelia Adams Brown. You were sometimes my cheerleader, sometimes my counselor, and other times my voice of reason. I have so much respect for you as a researcher, teacher, mother, and friend. You serve as living proof that women are strong and powerful and that there are no limits to what we can accomplish.

I must also acknowledge the friends who have kept me grounded and helped maintain my sanity over the last few years. I met Vita Mayes before I began working on my Master of Science degree several years ago, and she has been encouraging me and making me laugh ever since. I love you, Vita, and I am so excited to see what the new chapters of our lives will bring. Celia Winchester, our friendship is twenty-four years old and going strong, and I truly cherish every moment of that friendship. I admire your strength, compassion, and honesty. You are one of the hardest working women I know, and I truly believe you make this world a better place. Through Celia, I was lucky to meet Angi Hammaker and Megan Tuck. Angi, you are one of the most selfless souls I have ever met, and I will never be able to repay the generosity and kindness you have already shown me in our short time together. Megan, you are loyal, creative, and unbelievably talented. You love your friends fiercely, and I hope you see all the wonderful things in yourself that we all see in you.

My family has played a pivotal role during my doctoral journey. My grandfather, Robert Sharp (DaddySharp), has always been a role model and one of my biggest encouragers. He is a truly lovely man with a work ethic and natural intellectual ability I have always admired. Jim

Brewer, you willingly chose to become my father, even when I know it could not have been easy, and I will forever be grateful for the love you have shown both mom and me. Denise Hill, my mother, my rock, I cannot even begin to express how much you mean to me, and my eyes fill with tears when I try to capture these feelings in words. You are my best friend, I love you more than I could ever show or explain, and anything I ever accomplish in this lifetime would not be possible without you.

Lastly, I would like to express my gratitude for the individuals who participated in this study. These teachers allowed me to observe their classes and gave up precious planning time so that I could collect interview data and gain insight into their perspectives and instructional decisions. These participants truly impressed me with their passion for teaching and their pedagogical knowledge. These are incredibly inspirational humans who put copious amounts of hard work into their teaching practices each and every day. I believe I have grown both as a researcher and an educator as a result of getting to know them. Thank you.

Abstract

Current education reform agendas have stressed the need to improve equity in education, but action is needed beyond policy calls to ensure that all students have opportunities to reach their maximum potentials. Differentiated instruction and educational technology have the potential to help provide each student with the necessary tools, resources, and support to reach this goal. Few researchers have explored the role of technology in differentiating instruction in high school STEM-related classrooms. The purpose of this study is to explore high school STEM teachers' perspectives, decisions, and challenges related to the integration of educational technology for differentiation purposes in meeting students' diverse learning needs.

Cultural-Historical Activity Theory (CHAT) served as the framework to explore how seven high school teachers engaged in the activity of teaching STEM-related courses, with particular focus on these teachers' beliefs about the use of educational technology to differentiate instruction in the classroom and the specific strategies and technologies that were employed for differentiation. The affordances and challenges associated with the use of education technology for differentiated instruction were also examined. The findings of this study have implications for administrators and teachers who are looking to integrate educational technology to serve the needs of diverse learners in the classroom. The participants in this study did use educational technology for the purposes of differentiated instruction, although this appeared in different forms in each classroom. Several commonalities were also identified in this study, such as teachers' concerns about student misuse of technology and feeling overwhelmed with the time and effort required to research and integrate new technologies in the classroom. Additionally, the findings showed common benefits of using educational technology to differentiate instruction, including more flexible pacing and assignments that could be tailored to students' ability levels and interests. This research also provides a common language for researchers and practitioners to discuss the intersection between differentiated instruction and educational technology, along with the affordances and challenges involved in integrating both into teachers' pedagogical practices.

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Chapter 1

Introduction

The needs and goals of our society have evolved, as have the needs and goals of our educational system. Education no longer takes the form of the one room schoolhouse of the agrarian age, and the factory model of the industrial age also fails to meet our society's current needs (Reigeluth & Garfinkle, 1994). Our society currently exists in what is termed the information age, which "calls for a new educational system and paradigm, where students reach mastery through customized, personalized learning plans, and technology will necessarily be a critical element" (Watson, Watson, & Reigeluth, 2015, p. 332). To contribute to the current discourse on these subjects, this study focuses on teachers' decisions, actions, and perspectives concerning the integration of educational technology to help meet the needs of diverse learners within their classrooms. More specifically, this research aims to investigate how high school STEM teachers use educational technology to differentiate instruction in the classroom, these teachers' perspectives on the use of educational technology for differentiation purposes, including the benefits and challenges, and the factors that impact teachers' use of educational technology to different instruction. The surge of educational technology in the classroom, the need for differentiated instruction, and the intersection of the two are explored below.

This chapter describes the current educational landscape, including the emphasis on educational equity, technology, and STEM (science, technology, engineering, and math) education, and links each of these topics to differentiated instruction. This chapter also explicates the need for research related to educational technology and differentiated instruction in high school STEM classrooms and provides justification for the current study. With this dissertation, I explore high school STEM teachers' decisions and perspectives concerning the integration of educational technology to meet the needs of diverse learners in the classroom.

The needs of an increasingly diverse population of learners has resulted in education reform agendas that stress the need to improve equity in education (Barth, 2016; U. S. Department of Education, 2015a). For example, the Every Student Succeeds Act (ESSA), signed in 2015, demonstrated an increased emphasis on accountability and acknowledgement of the importance of education for all students, including those considered to be disadvantaged or high needs (U. S. Department of Education, 2015a). According to the Center for Public Education, educational equity is achieved when all students receive the resources necessary to prepare them to be successful after high school, yet barriers remain that prevent students from receiving this equitable world-class education (Barth, 2016). This research brief also states:

> Our ideas about equity have evolved to encompass more than a guarantee that school doors will be open to every child. Advocates are increasingly concerned with allocating the resources and opportunities to learn that will equip all students for success after high school, recognizing that some students require more support than others to get there. (Barth, 2016, pp. 1–2)

Action is needed to move toward equity in education so that all students have opportunities to succeed and reach their maximum potentials. The practice of differentiated instruction, which may be facilitated by the use of educational technology, can be used to help provide each student with the necessary tools and support to reach this goal (Duffey & Fox, 2012; Kaur, Koval, & Chaney, 2017; Kellerer et al., 2014). Differentiated instruction is discussed in greater detail below.

Diversity in Education

The cultural, ethnic, and racial diversity in our country and, therefore, the student population is increasing rapidly (T. C. Howard & Rodriguez-Minkoff, 2017). The distribution of race/ethnicity of students enrolled in public elementary and secondary schools in 2002 and 2012, as well as the projected distribution for 2024, is shown in Figure 1 below; according to this data, the percentage of students who are White is decreasing, and the percentages of students who are Hispanic, Asian/Pacific Islander, and two or more races are increasing (U. S. Department of Education, 2016b). Chronic achievement discrepancies and opportunity gaps continue to exist between students of differing language status, students who are White and students of color, and students with special needs and those without, despite educational reform efforts and calls for resource redistribution and societal transformation (Aragon, 2016; Howard & Rodriguez-Minkoff, 2017).

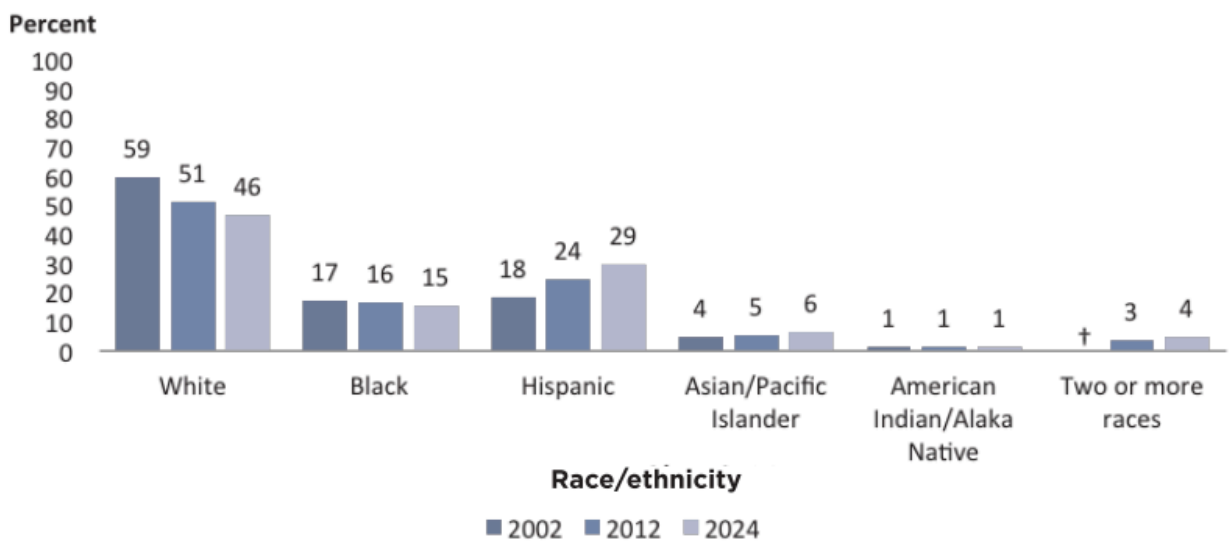

Figure 1. Percentage distribution of students enrolled in public elementary and secondary schools by race/ethnicity: Fall 2002, 2012, and 2024. (U. S. Department of Education, 2016b)

While our country's diversity is increasing (Keating & Karklis, 2016; United States Census Bureau, 2015; Wazwaz, 2015), the public elementary and secondary educator workforce has remained overwhelmingly homogeneous, with 82 percent of educators identified as White and 76 percent identified as female in 2012 (National Center for Education Statistics, 2013; U. S. Department of Education, 2016b). The figure below shows the percentage distribution of teachers in public elementary and secondary schools by race/ethnicity for the years 1987 to 2012; while there has been a slight decrease in the percentage of teachers identified as White, it continues to make up a staggering majority of the teacher workforce.

Certain issues may arise as a result of this lack of balance in diversity of the student population and the teacher workforce. One such issue is termed deficit thinking. Deficit thinking occurs when educators hold views and beliefs that students and their families are solely at fault

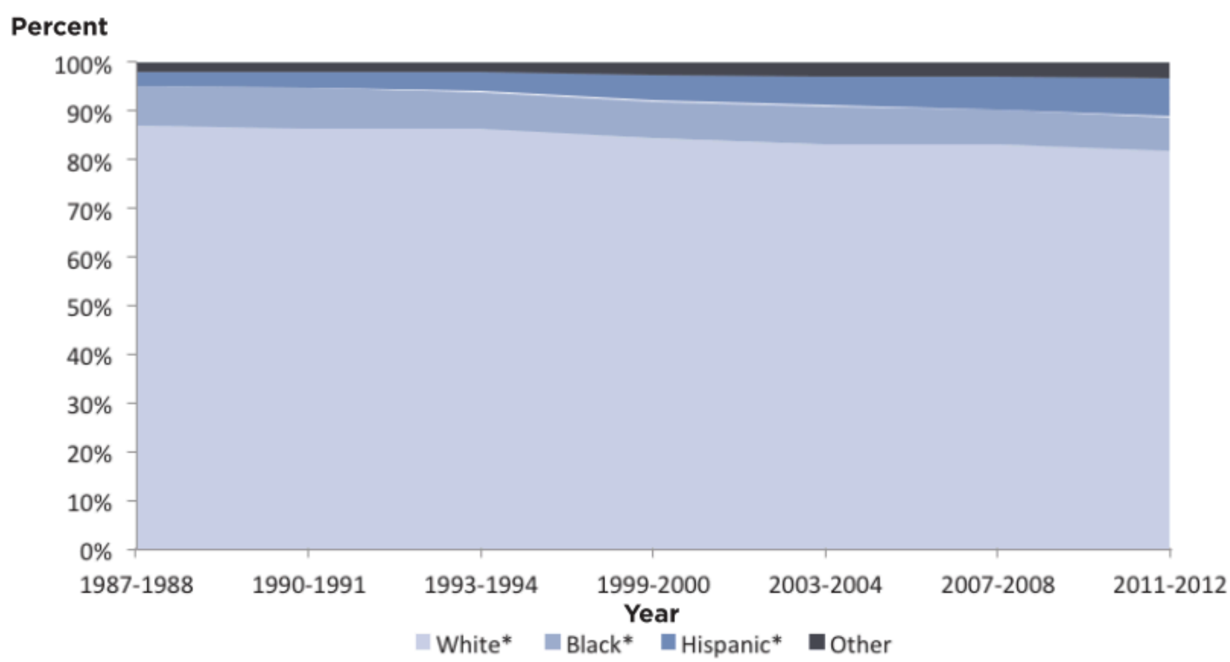

Figure 2. Percentage distribution of public elementary and secondary teachers, by race/ethnicity: 1987-88 through 2011-12. (U. S. Department of Education, 2016b)

when the students are not successful in school and that they themselves are not part of the problem, diminishing the initiative to search for solutions within the educational system (García & Guerra, 2004). These unexamined prejudices against students based on their racial, ethnic, and socioeconomic backgrounds lead to disproportionately labeling certain groups as underperforming (Anderson, 2013). Complacency and assumptions that there are no ways schools or teachers can educate diverse students more effectively "often lead to efforts to superimpose programs designed for historically successful students and families on students and on families from low-income and culturally/linguistically diverse (CLD) communities" (García & Guerra, 2004, p. 151). This deficit thinking perpetuates the achievement discrepancies and opportunity gaps between students of differing backgrounds (Anderson, 2013).

Teacher education programs typically rely on only one or two courses on multicultural education, social justice teaching, or culturally responsive pedagogy to prepare their predominantly White cohorts to teach ethnically and racially diverse students (Sleeter, 2017); however, studies show that this preparation is "not sufficiently potent to disrupt deficit theorizing about students, particularly in schools under pressure to raise student test scores" (Sleeter, 2017, p. 157). The curriculum of teacher education programs, as well as the curriculum in elementary and secondary education, and the testing required for teacher certification is Eurocentric and White dominated, further reinforcing the dominance of Whites in the teaching workforce (Milner, Pearman, & McGee, 2013; Sleeter, 2017).

Understandably, for many students, there is a disconnect between their personal, cultural experiences at home and their educational experiences at school (Ladson-Billings, 1995). In response to this disconnect, Banks and Banks (1995) describe the need for equity pedagogy, which is defined as "teaching strategies and classroom environments that help students from diverse racial, ethnic, and cultural groups attain the knowledge, skills, and attitudes needed to function effectively within, and help create and perpetuate, a just, humane, and democratic society" (p. 152). Integrating multicultural content is not enough – educators must employ instruction that recognizes, respects, and embraces the diversity of their students (Banks & Banks, 1995; Howard & Rodriguez-Minkoff, 2017). Ladson-Billings (1995) states that "culturally relevant teachers utilize students' culture as a vehicle for learning" (p. 161). The diversity within our classrooms is inherently valuable, having the potential to benefit our students by exposing them to differing experiences and perspectives and providing opportunities to breed innovation (U. S. Department of Education, 2016b).

Need for Differentiated Instruction

Despite the growing diversity in our classrooms (Musu-Gillette et al., 2016), educational practices continue to lean toward the "one-size-fits-all end of the flexibility spectrum" (Tomlinson, 2014, p. viii). Some people credit this absence or paucity of change to an increased emphasis on raising students' scores on high stakes standardized tests, leading some teachers to adopt a one-size-fits-all model in an attempt to get through as much of the curriculum as possible (Bogan, King-McKenzie, & Bantwini, 2012; Hershberg, 2005; Ingersoll & Collins, 2017; Subban, 2006). Subban (2006) warns against "the dangers of teaching to the middle" (p. 938) in a one-size-fits-all approach, making the argument that, in this approach, the more advanced students can lose interest and motivation while other students fall further behind.

To circumvent teaching to the middle, educators can employ differentiated instruction to make the curriculum accessible to students of all ability levels who have a multitude of different interests and backgrounds, with the goal of maximizing each students' learning and growth (Tomlinson & Allan, 2000). If instruction is delivered with only the needs of the average student in mind in a classroom containing students of various ability levels, backgrounds, learning preferences, and readiness, some students will feel left behind while others will feel that they are being held back (iLearn, 2005). Ford (2005) states that “common sense and personal experiences suggest that one size rarely fits all,” and “a single instructional response to a group of diverse learners often means that the teaching technique will help some while it ignores others” (p. 1). Education and knowledge should be accessible to all students, and differentiation can expand this accessibility and increase students’ academic achievement and overall enjoyment of academic learning experiences (Bray & McClaskey, 2013; Cavanagh, 2016; Hobgood, 2011; U. S. Department of Education, 2017).

Educational Technology

The amount of diversity within our classrooms and the need for differentiated instruction are not the only aspects of education that are changing. There are many intertwined components within any given classroom, including the interacting members of the classroom community and the available tools, such as educational technology. Increased accessibility to technology in schools also contributes to the dynamic, evolving environment of the classroom. New educational technologies are being adopted at an exponential rate; according to the Speak Up 2016 Digital Learning Report, 54 percent of school principals reported the implementation of digital content resulted in positive learning outcomes, and approximately half of K-12 teachers said they use technology to encourage student self-monitoring, to examine trends in student performance, and to provide feedback to students (Blackboard, 2016). In regards to educational equity, a digital divide does exist between students who have greater access to technologies at home and have grown to use these technologies in active, creative, academically-supportive ways and other students who either do not have access to technology or use these technologies to passively consume content or in ways that do not support their learning (Duffey & Fox, 2012; Harris, Al-Bataineh, & Al-Bataineh, 2016; U. S. Department of Education, 2017). These technologies, however, have the potential to provide differentiated student learning experiences in the classroom and better prepare students to succeed in future educational or professional careers (Bray & McClaskey, 2013; De Lay, 2010; Haelermans, Ghysels, & Prince, 2015; Hobgood & Ormsby, 2011; Reville, 2013; U. S. Department of Education, 2017), yet little is known about employing technology in the high school STEM classroom to suit the needs of diverse learners.

STEM Education

The education of science, technology, engineering, and mathematics, or "STEM," has also received increasing attention in the United States since the beginning of the 21st century (Chesky & Wolfmeyer, 2015). Education serves both economically and democratically linked purposes (Spring, 2014). Spring (2014) states, "Preparation for work or college is tied to a larger goal of improving the ability of the United States to compete in the global economic system" (p.3). Within this global economic system exists an increasing number of STEM occupations. As the number of STEM careers continues to grow, even more than non-STEM employment (Noonan, 2017), the emphasis on STEM education also increases.

There are several interpretations of the STEM reform initiative, including STEM education as a means to produce more highly competent and competitive workers for the global marketplace or STEM education as a source for essential knowledge for all future citizens, including minoritized and underrepresented groups (Chesky & Wolfmeyer, 2015). Problem-solving, gathering and evaluating evidence, and making sense of information are some of the crucial skills associated with STEM education (U. S. Department of Education, 2015b). The

National Research Council (2012) stated that, although “science, engineering, and technology permeate nearly every facet of modern life, and…hold the key to meeting many of humanity’s most pressing current and future challenges” (p. 1), people in the United States do not have sufficient backgrounds or knowledge in these fields.

As previously stated, current education reform stresses the importance of making STEM education accessible to all students (National Research Council, 2012; U. S. Department of Education, 2015b). The current educational inequity and emphasis on STEM suggests a need for the application of the principles of differentiated instruction to STEM education. The following section further details the current state of STEM education and the need for improvement in equitable education in STEM-related fields.

The science and engineering job market has exhibited sustainable growth for over half a century; however, according to the National Science Foundation (2014), the majority of U.S. high school students are not performing at proficient levels in math and science. Between 2009 and 2015, the National Assessment of Educational Progress (NAEP) science scores increased for grades four and eight but remained unchanged for twelfth grade (National Center for Education Statistics, 2017). In 2014, less than half of eighth-grade students who took the NAEP Technology and Engineering Literacy (TEL) Assessment scored at or above proficiency (National Center for Education Statistics, 2017). The TEL results showed higher scores for White and Asian students compared to Black and Hispanic students; furthermore, students who were not eligible for the National School Lunch Program scored significantly higher than those who were eligible, and there was a positive correlation between students' TEL scores and parental education levels (National Center for Education Statistics, 2017). This assessment data suggests that there are achievement gaps among students with varied race, ethnicity, and backgrounds. It should be noted, however, as mentioned previously, the tests created to assess students' understanding of the curriculum and the curriculum itself are Eurocentric and White dominated, which can create a disconnect between students' personal cultural experiences and their experiences at school (Milner et al., 2013; Sleeter, 2017); the curriculum itself is not neutral or equitable, and it is not designed for all students to succeed. According to Spring (2014):

> There is concern that standardized tests cannot be objective in measuring student learning. There are such things as test skills that can be learned…Also, the wording of questions can reflect particular cultural knowledge. Even someone who excels in math could miss a question in a standardized math test because of not knowing the meaning of a word due to limited cultural knowledge. (p. 228)

Furthermore, Spring (2014) argues that "accountability based on test scores can potentially contribute to greater inequality among school districts" since it has been reported that homebuyers may consider school test scores in their house selection, as "high test scores might be the most attractive to home buyers with school-age children" (p. 227).

The 2015 Programme for International Student Assessment (PISA) key findings show that the performance of the United States was below average in mathematics and around average for science and reading (Organisation for Economic Cooperation and Development, 2016a). PISA is a worldwide survey that aims to evaluate the skills and knowledge of 15-year-old students (Organisation for Economic Cooperation and Development, 2016b). The 2015 PISA results report described the need for focus on science, naming science as “ubiquitous in our lives” and “the basis of nearly every tool we use” (p. 2); this report also claimed that “science literacy is increasingly linked to economic growth and is necessary for finding solutions to complex social and environmental problems,” and “all citizens, not just future scientists and engineers, need to be willing and able to confront science-related dilemmas" (Organisation for Economic Cooperation and Development, 2016b, p. 6).

These statistics, along with an increased emphasis on STEM literacy, suggest a need for instructional strategies that make STEM content and skills more accessible to all students, including those who have not traditionally participated in STEM-related fields, to prepare them to compete within the global economy and successfully exist in a technology-infused society (Basham, Israel, & Maynard, 2010; Lawrenz, Huffman, & Thomas, 2006). Basham et al. (2010) argue "students with disabilities, those from culturally and linguistically diverse backgrounds, and those at risk for academic failure must be considered as integral parts of the general STEM education initiatives" (p. 12). Furthermore, a commitment to providing STEM education for all students involves moving beyond simply focusing on college and career readiness to focusing on the betterment of society as a whole (Basham et al., 2010). Success can take many forms, and, regardless of whether or not students pursue a college degree after high school, students can learn and develop valuable problem-solving and critical-thinking skills during their primary and secondary education. These skills may provide students with greater opportunities and help them become productive, successful citizens in the future.

Differentiated instruction can be viewed as a step in the direction of improving these educational opportunities for all students, even though differentiated instruction itself cannot solve the issues associated with the educational inequities mentioned above. There are systemic inequities that result from factors outside of the classroom and outside of the control of teachers and school administrators, such as course curricula and mandated testing for our public schools as determined by government agencies; these external factors, however, are not the focus of this study. This research will examine what can be done to address inequities within the classroom.

Considering the wide achievement gap between different student groups in STEM, using the affordances of educational technologies to differentiate instruction to provide access to equitable instruction makes sense. I will focus on this intersection in the next two sections by establishing the importance of differentiated instruction first, followed by the role of technology in differentiating instruction to serve the educational needs of all students in STEM.

Differentiated Instruction

Differentiated instruction is a strategy that involves approaching every student as an individual. It is an alternative to a one-size-fits-all approach to education. According to Hall (2002), "to differentiate instruction is to recognize students' varying background knowledge, readiness, language, preferences in learning, interests, and to react responsively" (p. 2). No two people are exactly alike so it is reasonable to expect that no two students learn in exactly the same way. The goal of differentiation, therefore, is to provide each student with the tools and motivation they need to achieve their highest potential. By identifying students' strengths, weakness, backgrounds, preferences, and prior knowledge, teachers can incorporate options and flexibility into their instructional strategies to maximize the learning and success for each individual student (Hall, 2002; Santamaria, 2009; Shawer, 2017; Stover, Sparrow, & Siefert, 2017). Differentiation may be explicit and obvious, or it may take more subtle forms. Anytime students within a single classroom are allowed to work and express their knowledge in different ways, teachers are using some form of differentiation (Benjamin, 2005). Benjamin (2005) explains that learning tasks can be differentiated by varying pacing, number of facets or components, overall structure, learner independence, and complexity.

There are certain terms associated with differentiated instruction that can cause confusion. For example, personalization, differentiation, and individualization are sometimes used interchangeably, but these terms have slightly different contexts and applications. Personalization, also called personalized learning, is learner-centered, with the learner taking control of their own learning (Bray & McClaskey, 2013). Individualization and differentiation, on the other hand, are teacher-centered; one of the primary differences between these two terms are a focus on adjusting to the learning needs of groups of learners in differentiation as compared to focusing on individual students' learning needs in individualization (Bray & McClaskey, 2013). All three approaches involve the use of data and assessments to monitor and advance learning.

While some may place importance on the distinct features of each of these terms, I believe it is possible that all three concepts can be incorporated and interwoven in a single classroom and even a single lesson. If differentiation and individualization are put into practice by an educator, the students may experience increased engagement and academic success; this may motivate students to take responsibility for their own learning and seek out knowledge related to their own interests and passions, resulting in personalized learning (Bray & McClaskey, 2013; Robinson, Maldonado, & Whaley, 2014; Stepanek, 1999; Tomlinson, 2014; Zheng, Warschauer, Hwang, & Collins, 2014). When students are more involved in the learning process, they feel they have a voice and a choice in their learning; they are more engaged in the learning process, resulting in less struggle and greater academic growth and success (Bray & McClaskey, 2013). If students are challenged and experience academic success, they may find themselves even more excited to learn and further accelerate their learning (L. Robinson et al., 2014). To best serve the purposes of the current study, the terms "differentiation" and "differentiated instruction" will be used to refer to both previously mentioned teacher-centered approaches, differentiation and individualization.

Role of Technology in Differentiating Instruction in STEM Education

Both the diversity of students and the accessibility of technology in the classroom are increasing. Technology has the potential to provide additional resources and flexibility to enable teachers to more efficiently tailor instruction to meet the needs of individual students within the classroom, rather than taking a one-size-fits-all or teaching to the middle approach (Blackboard, 2016; Hobgood & Ormsby, 2011; International Society for Technology in Education, 2016; Watson et al., 2015). There is also a need to make STEM education more accessible for all students, as described previously. Therefore, it makes sense to study the intersection of educational technology, differentiating instruction, and STEM education. If STEM teachers employ technology effectively with the goal of differentiating instruction, it may be possible to meet the needs of a greater number of students and positively impact learning for students of all backgrounds and readiness levels. Few studies, however, have specifically addressed the use of educational technology for differentiated instruction purposes in STEM-related classrooms. This study aims to investigate high school STEM teachers' perspectives on the use of educational technology for differentiation. Furthermore, this study examines the use of educational technology in the high school STEM classroom in order to identify benefits, challenges, and factors related to teachers' employment of this technology to differentiate instruction and meet the learning needs of their students.

Statement of the Problem

Educators are responsible for promoting educational equity, which involves maintaining high expectations for all students while providing them with quality opportunities to engage with the curriculum (National Research Council, 2012). Within a given classroom, even a classroom with students supposedly grouped by ability level or age, a wide range of learning styles and ability levels still exists. Tomlinson (2014) argues:

> Today's teachers still contend with the essential challenge of the teacher in the one-room schoolhouse: how to reach out effectively to students who span the spectrum of learning readiness, personal interests, and culturally shaped ways of seeing and speaking about and experiencing the world. (p. 1)

Teachers must attempt to utilize resources, time, and themselves to effectively maximize learning for all their students.

The diversity of students in our classrooms is increasing, with teachers being held accountable for the achievement of students who are from different cultural backgrounds and socioeconomic levels and have an array of learning styles and ability levels – below, at, and above grade level – increasing the need for differentiated instruction in the classroom (Blanton, Pugach, & Florian, 2011; Civitillo, Denessen, & Molenaar, 2016; Gomaa, 2014; Maeng & Bell, 2015; Musu-Gillette et al., 2016). Most studies about the use of differentiated instruction tend to focus on single aspects of differentiated instruction rather than working with a holistic view of the differentiated classroom; additionally, most of the research surrounding differentiation is placed in an elementary or middle school context, revealing a need for research on differentiated instruction at the secondary level (Benjamin, 2005; Maeng, 2016; Maeng & Bell, 2015). Additionally, there is a need to understand how to best utilize the available educational technology to meet the needs of all students within our schools and within STEM classrooms specifically.

Purpose of the Study

As stated above, most studies about differentiated instruction look at single components of differentiation rather than looking holistically at the interactions within the classroom and the factors influencing teachers' perspectives and decisions; in other words, these studies look at individual strategies of differentiation (e.g., grouping) without taking into consideration the totality of potential aspects of differentiated instruction and the intertwined contextual factors, such as the division of labor and rules, that influence the activity within the classroom. Furthermore, there is a significant gap in literature addressing the use of educational technology for differentiation purposes at the high school level. The goal of this study is to investigate secondary STEM teachers' perspectives and actions regarding the integration of educational technology to differentiate instruction in the classroom, while developing understandings of the factors that influence these teachers' use of educational technology for differentiation purposes.

Research Questions

The purpose of this study is to investigate ways high school STEM teachers differentiate instruction using educational technology to improve learning for students of all backgrounds and ability levels. This research is guided by the following questions:

1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?
2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?
    a. What specific educational technologies do STEM teachers use to differentiate instruction in their courses?
    b. What are the affordances of such technologies for differentiation?

c. What types of challenges do high school STEM teachers face when using educational technology for differentiation?

Definition of Terms

STEM education: "an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise" (Tsupros, Kohler, & Hallinen, 2009)

Differentiated instruction: an approach to academic instruction that involves a collaborative learning environment and curriculum that actively support learners and learning, acknowledgement of students' differences, flexible grouping, relevant assessment to evaluate students' understanding, and modification of content, process, and/or product according to students' interests, readiness levels, and learning profiles (Tomlinson, 2014)

Culturally responsive pedagogy: "using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning more relevant to and effective for them. It teaches *to and through* the strengths of these students. It is culturally *validating and affirming*;" also referred to as culturally sensitive, centered, mediated, reflective, and relevant (Gay, 2000, p. 29)

Educational technology: "the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (Januszewski & Molenda, 2008, p. 1)

Blended learning: integration of online/technology-based experiences and face-to-face instruction to achieve educationally meaningful learning goals (Fairbanks, 2014; Richey, 2013)

One-to-one technology: each student has access to an Internet-capable device to use for learning purposes (Costa, 2012)

Significance of Study

As previously described, the dynamic environment of the classroom is changing in many ways. The adoption of new educational technologies and the diversity of students are both increasing at a rapid pace (Blackboard, 2016; Bray & McClaskey, 2013; De Lay, 2010; Haelermans et al., 2015; Hobgood & Ormsby, 2011; Howard & Rodriguez-Minkoff, 2017; Musu-Gillette et al., 2016; Reville, 2013; U. S. Department of Education, 2017). In response to these changes, teachers must adapt to meet the needs of their students, who come from a wide range of backgrounds and with special needs and come to school with a plethora of personal interests, experiences, and readiness levels (Tomlinson, 2014). Although technology is becoming more accessible in most schools, the technology must not be viewed as a substitute for solid teaching; instead, technology should be utilized as a tool that can maximize learning opportunities to reach all levels of learners within the classroom, allowing every student to reach their maximum potential (Cavanagh, 2016; Marino, 2010; Mathews, 2012; Reich, 2012).

With the current emphasis placed upon STEM education and digital literacy, it is imperative that we develop a greater understanding of how technological tools can be put to the greatest use to improve learning for all students and prepare them for their futures beyond their high school education. With intentions of adding to the current discourse and knowledge of these issues, this study proposes to investigate how high school STEM teachers are using technology to differentiate instruction to reach diverse learners, as well as teachers' perspectives and the factors that influence the decisions and use of educational technology for differentiation purposes in the classroom. These understandings could provide insight that will aid in the development of strategies that could be used by administrators and teachers to integrate educational technology to the greatest benefit of all students.

Positionality and Commitments to Research

My academic and professional journey has taught me that education, teaching, and learning are complex, intertwined concepts. I have taken on the role of student, first as a student of Tennessee's public school system and again as a college and graduate student at the University of Tennessee. I have performed laboratory-based quantitative research in the natural sciences during my work as a student in the Biochemistry and Cellular & Molecular Biology Master of Science program. In 2011, I began teaching science in public school systems. Now, I find myself in three roles at once: secondary science teacher, doctoral student, and education researcher.

My evolution through each of these roles has shaped my perspectives regarding education and technology. I have experienced a wide range of responses to educational technology and the practice of differentiated instruction in the high school classroom. Some teachers are uncomfortable with technology in the classroom, and some teachers expect it to be a sort of a silver bullet to solve all of problems with education. I feel technology has the potential to be an extremely valuable tool used to expand our teaching repertoire and make education more accessible to the diverse populations of students in our classrooms.

In my own high school biology classrooms, I have seen all of the following within a single class: some students struggle with learning content because of their ability levels or learning styles; some students are bored because they have already mastered the concepts being presented and are waiting on other students to catch up; and some students lack motivation or engagement in the lesson because of external factors or they fail to see the relevance or benefit in learning the content. Although I have been told that differentiation does not happen at the high school level, collaboration and discussion with colleagues and my own experiences as a teacher suggest otherwise. Some teachers do not consider what they do as "differentiating instruction," but they are incorporating strategies to meet students' varying needs – the matter that lies at the heart of differentiation. The research interests of the current study result from a combination of my own personal appreciation for technology and the benefits that I have seen from integrating technology into my own classroom. By conducting this study, I hope to elucidate some of the issues surrounding the use of educational technology for the purposes of differentiation in high school STEM classrooms. Even if findings are not entirely transferable to other schools or classrooms, the implications may add to the current discussion of how educational technology can aid in meeting the needs of diverse learners.

Organization of Dissertation

To guide readers through the content of this dissertation, I am including this overview of the remaining chapters. Chapter two provides the research context of the topics of differentiated instruction in general, as well as differentiated instruction as it relates to educational technology and STEM education. The methodology selected for this study, which employs a collective qualitative case study approach and is framed by Cultural-Historical Activity Theory, is detailed in chapter three. Chapter four describes the data as analyzed from individual cases in the within-case analyses, as well as the cross-case analysis of all seven cases. Lastly, a final discussion, along with the conclusions and implications of this dissertation research, is presented in chapter five.

Chapter 2

Review of the Literature

The previous chapter has provided an overview of the current state of STEM education and educational technology in the classroom and introduced the concept of differentiated instruction. In Chapter 1, the case was also made for the need for differentiation in the classroom based on the growing diversity of students within our classrooms. Considering the recent surge of interest in STEM education and increases in both student diversity and accessibility to technology, the current study examines the intersection of these three issues. More specifically, this study aims to investigate if and how high school STEM teachers use educational technology to differentiate instruction and improve learning for students of all backgrounds and ability levels. This calls for a review of relevant literature on differentiated instruction and educational technology in the field of STEM education. This literature review will expound on the implementation of differentiated instruction and its benefits and challenges, as well as explore connections between differentiated instruction, educational technology, and STEM education.

Differentiated Instruction

Implementation of Differentiated Instruction

Benjamin (2005) describes differentiated classrooms as "widely heterogeneous, dynamic, purposeful, and intense" (p. 1). While differentiation can materialize differently depending on the teacher, students, curriculum, and available resources, there are some commonalities among differentiated classrooms. Teachers of differentiated classrooms begin with the understanding that there are certain content requirements, or “standards,” and that their classes will consist of students who vary as learners in immensely different ways (Tomlinson, 2014, p. 3). Teachers determine the skills and concepts that students need to learn based on the curriculum and standards, which are typically either nationally or state-mandated, and this content is made more accessible to students through the use of differentiated instruction (Benjamin, 2005).

The theory of differentiated instruction can be linked to constructivism and Lev Vygotsky's (1978) notion of the zone of proximal development (ZPD) (Santamaria, 2009; Subban, 2006). Constructivism frames the learning process as both social and communicative, with knowledge being constructed and shared among learners in various situations (Vygotsky, 1978). From a constructivist standpoint, individuals "construct their point of view of the world, philosophy of living, technical expertise, and knowledge structures," and there is emphasis on the social and situational learning experiences and learning initiatives (Ouyang & Stanley, 2014, p. 161). Piaget is also credited with contributing to constructivism; Piaget's theory focused on how an individual's ways of doing and thinking evolve over time, at different levels of development (Ackermann, 2001; Piaget & Inhelder, 1956). Papert (1993) built upon Piaget's theory by focusing on the art of learning, describing the significance of externalizing inner feelings and ideas and of creating artifacts or representations (Ackermann, 2001).

In a typical classroom, the social and communicative nature of constructivism is evident as students and teachers interact and work together to construct knowledge, allowing students to learn and develop understandings with the help of more knowledgeable others as they operate within what is termed their zone of proximal development (ZPD). Vygotsky (1978) described the zone of proximal development as the relationship between a learner's independent problem-solving capabilities and their problem-solving capabilities with the guidance of an adult or more capable peer, linking what is known to what is not known (Subban, 2006). The zone of proximal development has no finite boundaries; it is fluid and dynamic, depending on the content, context, and learner characteristics (Dimitriadis & Kamberelis, 2006; Vygotsky, 1978). Researchers often refer to ZPD as a pedagogical tool, artifact, or variable that can be manipulated; however, from a Cultural-Historical Activity Theory (CHAT) perspective, which is the framework guiding the current study, ZPD "is a conceptual tool for understanding the complexities involved in human activity while individuals engage in meaning making processes and interact with the environment" (Yamagata-Lynch, 2010, p. 19).

Considering the amount of diversity within each classroom, students can also be expected to vary in terms of their zones of proximal development and, consequently, the type and amount of support and scaffolding they may need. Teachers become facilitators, helping students reaching and extending their zones of proximal development. If students within a classroom are at differing developmental levels, a single approach may not be appropriate to meet the needs of each of these students. Therefore, educators must incorporate strategies and methods that will provide flexibility and allow for differentiation of instruction to meet each learner's needs and maximize learning opportunities for each student.

In addition to cognitive differences, students also possess a wide range of interests, prior experiences, cultural backgrounds, learning preferences, and access to resources and supports at home (Civitillo et al., 2016; Landrum & McDuffie, 2010; Organisation for Economic Cooperation and Development, 2008; Richards & Omdal, 2007; Stanford, 2003; Subban, 2006). In 2016, almost one-fifth of the population of children in the United States were living in poverty (Kids Count Data Center, 2017), and achievement gaps continue to exist between students of low socioeconomic status and their wealthier peers (Barth, 2016). Students who encounter discontinuity between their experiences at home and at school, including those who are not part of the White, middleclass mainstream, may find it difficult to engage and identify with the content; these students may be unable to develop connections between their culture and their education (Ladson-Billings, 1995). Teachers who practice differentiated instruction recognize that each student is unique in each of these aspects and seek ways to connect with students to help them engage with the content and develop the tools and understanding needed to experience success and growth (Benjamin, 2005; Tomlinson, 2014).

Teachers of differentiated classrooms build relationships with their students and learn about their backgrounds, personal interests, and learning preferences to better mold their instructional strategies to optimize student learning (Baglieri & Knopf, 2004; James, 2009; Tomlinson & Imbreau, 2013; Tomlinson & Kalbfleisch, 1998). These teachers also assess students' prior knowledge and current ability levels to determine the best plan of action and develop lessons that will challenge and motivate each student to achieve their goals and gain a deeper understanding of the content and skills being presented (James, 2009; V. Park & Datnow, 2017; Stover, Sparrow, & Siefert, 2017; Tomlinson, 2014). Differentiated instruction is complex and multi-faceted; specific components of differentiated instruction are addressed in the sections below.

General Characteristics of Differentiated Instruction

While differentiated instruction can materialize in various ways depending on the styles and strengths of each teacher and the needs of each group of students, there are some general principles of differentiated instruction implementation. The general principles of differentiation include flexible grouping, ongoing and relevant assessment, and respectful tasks for all students (Tomlinson & Allan, 2000). Each of these principles is described in greater detail below.

Grouping. According to Park and Datnow (2017), "the types of student groupings, the purpose of grouping, and the malleability of groupings matter" (p. 282). In flexible grouping, students may work individually, in small groups, or as an entire class, depending on the task and purpose of the lesson. Groups may consist of students with similar readiness, ability levels, interests, or learning patterns; alternatively, students may be grouped heterogeneously or even randomly (Tomlinson & Allan, 2000). Sometimes grouping arrangements are determined by the teacher and other times by the students. Consistent and purposeful flexible grouping can provide multiple benefits, such as allowing students to participate in learning in multiple contexts and settings and providing opportunities for more precise and individualized teaching and learning (Tomlinson & Allan, 2000).

Choices of grouping can serve different purposes and have different advantages and disadvantages. For example, homogeneous small groups can allow for different materials or texts to be used in each group and for instructions to be specialized to meet the needs and abilities of each group; however, students may also feel a certain stigma if they feel they are in a lower level group (Ford, 2005). Teacher bias and deficit thinking, discussed in the previous chapter, can also influence how students are grouped, perpetuating educational inequities and negatively impacting students' learning experiences (Anderson, 2013; García & Guerra, 2004). In other words, the unexamined prejudices that teachers may hold against particular groups of students based on their racial, ethnic, and socioeconomic backgrounds can lead to disproportionately and incorrectly labeling these students as under-performing, which may materialize in certain homogeneous grouping scenarios. Whole-group instruction may create a sense of community within the classroom and be viewed as more efficient in providing instruction to all students, but some students may become disengaged if they do not find the content or skills to be challenging or, at the other end of the spectrum, attainable (Ford, 2005). Mixed-ability grouping, where students of differing ability levels work together, may be used to provide struggling students with support from higher-performing students as well as to “engage students’ unique perspectives for complex problem solving" (V. Park & Datnow, 2017). In one approach called jigsawing, different groups of students are assigned different parts of a text or assignment, and differentiation can be implemented by matching the assigned texts or assignments with students' ability levels or by modifying the level of teacher support for each group (Ford, 2005).

Doubet (2015) reiterates the importance of grouping in her journey to create a differentiated classroom to improve the engagement and learning of her students. Despite feeling unprepared at the beginning of her teaching career, Doubet's teaching repertoire expanded to include cooperative learning groups and, eventually, the more dynamic flexible grouping that is characteristic of differentiated instruction. Through trial and error, Doubt found that the most successful flexible grouping occurred when students were given explanations that they would be trying new things, grouped in various ways (such as randomly, by commonalities, heterogeneously, by readiness, and by student-choice), and provided with written directions so all groups could work on different tasks simultaneously.

Assessments. As stated by Farrell and Rushby (2016), "Assessment is the process of identifying, collecting, and interpreting information about learning outcomes. It is an integral part of the teaching, training and learning cycle" (p. 107). Assessing student learning is an integral and valuable component of differentiated instruction (Ernest, Thompson, Heckaman, Hull, & Yates, 2011). Ongoing, relevant assessment involves taking measures of students' needs and current understanding of content throughout the entire learning process (Tomlinson & Allan, 2000). To provide opportunities for students to connect new material to prior knowledge, teachers can employ pre-assessments to investigate what types of prior knowledge students already have to build upon (Riccomini, Sanders, Bright, & Witzel, 2009). In differentiated instruction classrooms, teachers use data gathered from formative assessments, which can be either formal or informal, to understand how each student is connecting with the curriculum, to correct errors and misconceptions quickly, and to adapt future lessons so they work best for each student (Riccomini et al., 2009; Tomlinson, 2014; Tomlinson & Allan, 2000).

Assessments can take multiple forms, and differentiation takes place when these forms are matched to students learning styles, preferences, or ability levels (Benjamin, 2005). While assessments can be performed using typical pencil-and-paper tests or quizzes, which can be varied by complexity to accommodate student ability levels, alternative assessments can also take on several different types and forms. Some examples of alternative assessments include writing a creative essay or letter, maintaining a portfolio or a log of activities and reflections, creating a presentation or demonstration, or completing an authentic performance-based task. These alternative assessments can provide students with opportunities to demonstrate their learning and understanding, giving teachers a more holistic picture of their students' abilities and areas in need of further improvement (Benjamin, 2005; Job, 2011). Teachers can use the results from these assessments to tailor future lessons and activities to provide intervention or enrichment to students as needed.

Respectful tasks. Based on the data obtained from ongoing assessments, relevant and respectful tasks are assigned for each student. According to Tomlinson & Allan (2000), respectful tasks for each student are tasks that “provide equal access to essential understanding and skills” and are considered to be “equally interesting and equally engaging” (p. 7). These respectful activities should be stimulating and appealing, while focusing on essential skills and concepts (Metropolitan Center for Urban Education, 2008). Differentiation does not mean each student has to receive an entirely different task; tasks can be designed to have enough flexibility in arrangement, products, and complexity that allow for each student to be challenged and find an appropriate fit for their individual learning (Tomlinson & Allan, 2000). For instance, tiered assignments can be used to explore similar content by varying levels of complexity and depth, making the task suitable for each student's personal readiness level (Benjamin, 2005; Tomlinson & Kalbfleisch, 1998). Learning activities can also be designed to pique students' interests by providing students a real world context; in one example of a respectful task described by Banks and Banks (1995), a physics teacher transformed a unit on torques by allowing students to investigate and analyze the collapse of an actual bridge and use their findings to design their own bridges. In this example, students were able to both exercise choice and link the content to a relevant, real world situation, increasing students' interest and engagement levels in the learning task.

Our students have a wide range of learning preferences, interests, ability levels, accessibility to resources, and racial and ethnic backgrounds, as mentioned above (Barth, 2016; Organisation for Economic Cooperation and Development, 2008; Tomlinson, 2014). If students are able to link their own culture and interests to the content, they are more likely to develop a deeper understanding of that content and to experience academic success (Ladson-Billings, 1995). Respectful tasks can be considered a part of culturally relevant pedagogy since these tasks utilize the strengths, cultural knowledge, and previous experiences of our diverse students to improve the effectiveness and relevance of student learning (Gay, 2000). Howard (2003) argues that it is imperative for teachers to understand that diverse students bring "cultural capital," such as language, behaviors, social practices, and ideologies, that often vary drastically from mainstream norms (p. 197). Teachers should respect and embrace these differences and unique perspectives to provide all of their students with valuable learning experiences that are more personally meaningful, inclusive, and relevant to real world.

Differentiating content, process, product & learning environment. The general principles of differentiated instruction can be applied to decisions concerning content, process, product, and learning environment (Tomlinson, 2014). Content can be tailored to meet the needs of individual students in several different ways. For example, a teacher may use manipulatives with certain students to help them understand a concept or different spelling or vocabulary lists for students of varying ability levels (Tomlinson & Allan, 2000). Benjamin (2005) explains "differentiating content means that students will be learning different information about the same topic" (p. 20). Texts can also be given to students at different reading levels, and concepts can be presented in different formats and with different approaches, such as part-to-whole and whole-to-part (Moore & Bintz, 2002; Tomlinson & Allan, 2000).

The process or activity by which students come to understand a concept or skill can also be differentiated by providing options based on students' ability levels or students' interests or by varying the amount of support provided as students complete a task (Tomlinson & Allan, 2000). Choice boards are one way of differentiating by process or activity. A choice board presents students with tasks organized by learning style, by time frame required to complete each task, or by skill and readiness levels (Benjamin, 2005). Students can decide which activity or process is most appealing and engaging to them. For example, students may be given the option of accessing content by reading a textbook, engaging in a more hands-on activity, watching a presentation, or conducting internet research (Maeng & Bell, 2015). Varying levels of scaffolding, or "supports provided to students to assist them in making cognitive growth just beyond their reach" (Bell, 2010, p. 41), can be applied to these activities to further differentiate instruction and ensure the success of diverse learners.

Products can be tailored to meet the needs of individual students in numerous ways. In a differentiated classroom, the teacher may allow students to help design these products or choose from various types of expression, or teachers may vary the difficulty of assigned products or employ multiple types of assessment (Tomlinson & Allan, 2000). The artifacts produced from the choice board mentioned above may also be viewed as differentiated products if they are used as an assessment of student learning and understanding. Additionally, students may be allowed to choose between taking a traditional paper-and-pencil test, turning in a written report, or giving an oral report or presentation (Benjamin, 2005).

Learning environments should be emotionally safe places for learning to take place, and these environments can also provide opportunities for differentiation (Tomlinson & Kalbfleisch, 1998). The environment of the classroom should be both productive and positive, fostering collaboration and facilitating student activities (Maeng & Bell, 2015). Tomlinson and Imbreau (2013) list several pieces of evidence of classroom environments that support differentiated instruction. Characteristics of classroom environments that foster differentiation include the following: development of respectful relationships among teachers and students, encouragement of creativity, activities that facilitate students in seeing one another in varied contexts and roles, and opportunities for student choice and input in making decisions that affect the class (Tomlinson & Imbreau, 2013). The physical space of the classroom should be conducive to the grouping and mobility of students and allow them to access needed resources and materials.

Challenges and Benefits of Differentiated Instruction

Differentiated instruction can be implemented in several different ways, depending on the teacher and the specific needs of the students. Differentiation is a complex and dynamic approach to teaching that carries with it both benefits and challenges. Examination of the literature surrounding differentiated instruction uncovered several prevalent benefits and challenges, discussed in greater detail below.

Differentiated instruction has been found to benefit both teachers and students by increasing students' intrinsic motivation, achievement, and engagement and by improving students' attitudes toward learning (Maeng & Bell, 2015; Mastropieri et al., 2006; Richards & Omdal, 2007; L. Robinson et al., 2014; Waters, Smeaton, & Burns, 2004). Differentiated instruction can provide students with a sense of choice and control and facilitate the building of a positive environment and relationships within the classroom, which can also lead to increased student engagement throughout the learning process (Maeng, 2016; Richards & Omdal, 2007; Waters et al., 2004). Integrating the element of choice can give students opportunities to explore their own interests and experience deeper learning while also allowing students to learn at their own pace and readiness level (Bell, 2010; Stetson, Stetson, & Anderson, 2017). When students are provided with resources that meet their specific needs, such as text-based materials suitable for their reading levels or content presented in their personal learning styles, students can learn at their own levels and may reach to even higher levels to gain access to more challenging material and deeper knowledge (Bell, 2010, p. 41). Differentiated instruction has the potential to improve learning experiences for students of all ability levels and backgrounds (Tomlinson, 2014). The flexibility and meeting of students' individual needs can help students who may have fallen behind to catch up while also providing opportunities and resources to students who are ready to bolster their skills and develop deeper understandings of more complex material.

Despite these potential benefits, some teachers find difficulty in implementing these student-centered practices due to conflicts with covering all the standards in preparation for standardized tests (Basham et al., 2010). Other barriers to differentiated instruction include teachers' beliefs, access to resources and instructional materials, administrative support, and preparation and cultivation of teachers' pedagogical knowledge and skills (Maeng, 2016; Maeng & Bell, 2015; Mastropieri et al., 2006). Robinson, Maldonado, and Whaley (2014) found that teachers expressed concerns with time constraints, a lack of professional development, and difficulties with learning how to begin differentiating instruction; these teachers also cited the following obstacles to implementing differentiation: fear of losing control of students, trying to incorporate too many ideas and subjects at once, and the amount of time required to differentiate instruction.

One recent study by Stetson, Stetson, and Anderson (2017) highlighted both benefits and challenges of differentiated instruction. After reading a book about differentiated instruction, forty-eight elementary teachers were asked to design and teach four lessons differentiating various aspects of instruction: content, process, product, and a combination of all three (Stetson et al., 2017). These reflected on their experiences with differentiating instruction and later shared these experiences. The teachers' perceived benefits of differentiated instruction in this study included: students’ motivation to stay engaged in learning, meeting of students’ needs, increased student success and feelings of more relevant learning, greater student ownership of learning, and new insights about developing innovative instructional strategies. Challenges of differentiation were identified as a difficult learning curve, as teachers felt learning about differentiated instruction and designing and implementing lessons tailored to multiple learning styles and intelligences was overwhelming and daunting. Teachers also had difficulty finding time to plan for these more complex differentiated instruction lessons. There was a unanimous opinion among these teachers, however, that the benefits of differentiated instruction outweighed the challenges (Stetson et al., 2017).

As shown above, the practice of differentiated instruction carries with it numerous potential benefits as well as some potential obstacles or challenges. As the diversity of our classrooms increase, however, it is imperative that we rise to meet these challenges and overcome these obstacles to find ways to meet the learning needs of all of our students. Differentiation strategies can be employed in any classroom, include STEM-related classrooms. The next section describes research involving the use of differentiated instruction in STEM education.

Differentiated instruction in STEM education

While implementing differentiated instruction involves various challenges, as mentioned previously, studies (Bal, 2016; Maeng & Bell, 2015; Mastropieri et al., 2006; Richards & Omdal, 2007; Trinter, Brighton, & Moon, 2015; Zheng et al., 2014) suggest that differentiated instruction is already occurring in some STEM classrooms. Tanner and Allen (2004) make a case for the use of differentiated instruction in the science classroom; science educators need to address learning styles to engage all students to "[draw] a more diverse group of students into science will enrich our own experiences and bring a new strength and diversity to our scientific enterprise" (Tanner & Allen, 2004, p. 201). Methods of implementing differentiated instruction appear frequently throughout studies of differentiation in STEM education. As described previously, these methods include differentiating by content, process, product, ability levels, learning styles, and multiple intelligences. Alternative assessments, flexible grouping, and the classroom environment can also be used to tailor instruction to meet the needs of diverse learners. This section describes studies that investigate the use of differentiated instruction in STEM education.

Maeng and Bell (2015) conducted a descriptive study to examine how secondary science teachers incorporated differentiated instruction into their practice. Using semi-structured interviews and classroom observations scored using the validated Differentiated Instruction Implementation Matrix-Modified instrument, the researchers found that all seven participants were implementing differentiation through instructional modifications to some extent. All teachers included in this study employed differentiation strategies that required little preparation, and four of the seven teachers were applying instructional strategies requiring more extensive preparation. Low-preparation differentiation strategies included allowing students to choose an activity from a learning menu, to choose the order in which activities were completed, or to decide to work individually or with others. More complex differentiation strategies that required a higher level of preparation included tiering and flexible grouping based on data from formative assessments. This study shows that differentiated instruction is currently being used in STEM-related classrooms to enhance student learning and to try to meet the needs of diverse learners.

Gomaa (2014) conducted a study involving differentiating instruction with middle school science students with learning disabilities. The experimental group students participated in three weekly after school sessions over the course of 2 months during which they worked together on homework tasks that incorporated seven different intelligences, based on Gardner's theory of multiple intelligences. The pre- and post-assessment scores of the experimental group students were compared to the scores of control group students, who did not participate in after school intervention sessions. Gomaa (2014) found that differentiating instruction using multiple intelligences improved achievement in and attitudes toward science, compared to students who learned using traditional teaching methods.

Another study by Richards and Omdal (2007) examined the effects of tiered instruction on high school students' achievement in science. This quasi-experimental study included seven treatment classes and seven control classes. All student participants were given an assessment to determine their level of background knowledge of astronomy and Newtonian physics. The control classrooms received nontiered midrange instruction, while the students in treatment classes were grouped according to their level of background knowledge and received tiered instruction with learning materials and activities scaffolded for each background knowledge level. Pre- and post-assessment scores were compared for each background knowledge sub-group for treatment and control classes. Although the results did not indicate that the tiered instruction significantly increased achievement for the students with middle and high background knowledge levels, the incorporation of tiered instruction and flexible grouping did improve the academic performance of students of lower readiness levels.

Another study based in a secondary science classroom explored the alternative assessment aspect of differentiated instruction from students' perspectives (Waters et al., 2004). Students could choose between multiple types of assessment activities and between working in small groups or alone. Board games, computer presentations, web pages, live performances, and three-dimensional models were among some of the assessment products. Surveys and questionnaires were used to collect data about students' attitudes and beliefs concerned the alternative assessments. The findings showed that most students in this study preferred differentiated, alternative assessment over traditional assessment methods (Waters et al., 2004).

Differentiating instruction presents numerous benefits and challenges in STEM education, as well as education in general. Differentiation assists teachers in addressing each students' learning needs and can lead to increased student achievement (Gomaa, 2014; Maeng &

Bell, 2015; Mastropieri et al., 2006; Servilio, 2009). In addition to these benefits, several challenges or obstacles exist when differentiating instruction in STEM classroom. Teachers' beliefs, lack of administrative support or professional development, and limited time and resources can present barriers to differentiating instruction (Maeng, 2016; Maeng & Bell, 2015; Mastropieri et al., 2006). For instance, Robinson et al. (2014) suggest some educators "[consider] differentiated instruction to be another educational trend that will quickly pass and be replaced with something new" (p.3).

As previously stated, most studies involving differentiation in STEM classrooms do not take a holistic approach, focusing on singular aspects of differentiated instruction. The majority of these studies are situated within the context of elementary and middle schools, each school with a different level and quality of resources, serving students with unique characteristics, and teachers operating with unique pedagogical beliefs and preparedness for differentiating instruction. Considering this synthesis of issues related to current state of differentiated instruction in STEM education, further research is needed to explore how differentiation can be applied in secondary STEM education to meet the needs of all students. More specifically, this study explores the role of technology in creating differentiation in STEM classrooms. It is important to pursue this inquiry because the role of technology in creating equitable educational opportunities for all students through differentiation has been understudied in STEM.

Differentiating instruction with educational technology

Technology is associated with a multitude of daily experiences, such as working, going to school, shopping, and even enjoying free time. Technology is also increasingly permeating teachers' and students' educational experiences (Blackboard, 2016), and the current education reform agenda stresses the importance of increasing students' digital literacy and improving skills involved with utilizing technology (International Society for Technology in Education, 2016; U. S. Department of Education, 2017). The influence of technology can be seen in recent national education reform initiatives, such as the *Next Generation Science Standards* with increased emphasis on core engineering and technology ideas (NGSS Lead States, 2013). In another example, the Common Core Standards for Mathematical Practice describe the importance of strategically using appropriate tools, including technological tools such as spreadsheets and calculators (National Governors Association Center for Best Practices, 2010). This emphasis on improving the digital literacy and technological skills of all students is accompanied by a movement where many students are gaining access to learning opportunities from any location and at any time of day (U. S. Department of Education, 2017). The goals of the 2016 National Education Technology plan include making "everywhere, all-the-time learning possible," and "ensur[ing] equity of access to transformational learning experiences enabled by technology" (U. S. Department of Education, 2016a).

As previously stated, within any given classroom, there exists a diverse group of students with a wide range of backgrounds, learning styles, and ability levels, calling for teachers to adjust and adapt instruction to meet the unique needs of all their students (Blanton et al., 2011; Civitillo et al., 2016; Gomaa, 2014; Hobgood, 2011; Musu-Gillette et al., 2016; Subban, 2006; Tomlinson, 2014). To accomplish this task, teacher can differentiate instruction in relation to process, content, product, and climate (Hobgood, 2011). Each of these areas plays a role in students' learning experiences, and each of these areas can be affected and even transformed by the integration of educational technology in the classroom.

Despite the widespread availability of technology, especially in technology-rich environments, such as one-to-one schools, teachers with access to technology that could increase opportunities for differentiated learning and possibly student growth and achievement may not be employing this technology to address the learning needs of diverse students. Simply inserting technology into a classroom does not automatically cause students to learn (International Society for Technology in Education, 2016); however, effectively implementing and integrating technology into research-based instructional practice could provide opportunities to maximize learning and reach a wider range of students (Hobgood & Ormsby, 2011). Customized learning that incorporates transformative technology has the capability to provide students with more learner-centered experiences, rather than the one-size-fits all educational approaches of the past (Watson, Watson, & Reigeluth, 2015). Technology has the potential to enhance personal learning environments by allowing for more student control in the education process, contributing to students' collective learning, and advancing individual meaning making (Rahimi, Berg, & Veen, 2015).

Hobgood and Ormsby (2011) argue in favor of the use of digital tools, such as virtual manipulatives, video tutorials, and recorded lectures, to increase the accessibility of content and improve comprehension for students who require processing time; students can use these digital tools to review material as many times as needed, without the time constraints and limited availability of a singular lecture from an instructor. Content contained within a reading passage, which could be related to science, math, or practically any subject, can be augmented to meet the needs of diverse learners through the use of screen-reading software, concept mapping programs, digital textbooks, audiobooks, ebooks, and even highlighting features in word processing software (Hobgood & Ormsby, 2011). These technologies can deliver content in numerous ways and at varying levels of difficulty, allowing students to engage in the content using their preferred mode of delivery or learning style and even potentially strengthening areas of weakness by providing students with opportunities to practice less familiar or less dominant intelligences, as previously mentioned in the discussion of Gardner's theory of multiple intelligences (Gardner, 1997).

Christine Levinson, an assistant principal at a high school in Los Angeles, California, described the use of a small-group focused, blended learning environment that integrates technology into the classroom to allow learners to work at their own pace while freeing up teachers to work to target students' specific needs (Association for Supervision & Curriculum Development, 2017). Web 2.0 tools and technologies, such as wikis, YouTube, blogs, and Skype, provide increased access to information and opportunities for communication, collaboration, and even personalization of learning experiences (Conde et al., 2014; Rahimi et al., 2015). Additionally, technology can provide individual support and reinforcement outside of the classroom in the form of e-tutoring (Corrigan, 2012; Ranganathan, Vanlehn, & Van De Sande, 2014).

Educational technology was used for differentiation at Henry County schools in Georgia when they redesigned their personalized learning program, using sessions called “WIN” (for What I Need) to better meet their students' needs (Cavanagh, 2016). One day a week was devoted to providing students with additional academic support in the subjects of their choosing, such as math and science, which required more practice or help. During this time, students worked individually or in small groups in a blended learning environment. In this new model, the technology was no longer the focus, but, instead, the tool used to accomplish students' learning goals. Technology provided flexibility in pacing and additional resources for struggling students to catch up while others had opportunities to experience enrichment and even deeper learning.

The program allowed increased autonomy and individual students' decision-making, which in turn strengthened students' ownership of their own learning (Cavanagh, 2016).

As elucidated above, students come from a variety of backgrounds and with differing experiences and ability levels, requiring teachers to differentiate instructions to meet the needs of these diverse learners, and educational technology can be used as a tool to facilitate this differentiation (Marino, 2010). Technology should be viewed as an instrument that can be used to enhance learning and accomplish differentiated instruction goals, but technology alone is not a solution; it must be employed alongside solid pedagogical strategies to truly have a positive impact on student learning. The following section provides a review of research conducted to examine how educational technology has been used to differentiate instruction specifically in STEM-related classrooms.

Differentiating instruction with educational technology in STEM Education

Few researchers have explored the role of technology in differentiating instruction in STEM education. A search of the Education Source database for the following terms "educational technology," "individualized instruction" (the term recognized by the database as differentiated instruction), and "STEM education" produced a single result – a study by Zheng et al. (2014) on the impacts of laptop use on fifth graders' learning and achievement in science and interest in further STEM study. A search within this same database for "educational technology," "individualized instruction," and "science education," produced only sixteen results, five of which were published before the year 2000. Searching for "educational technology," "individualized instruction," and "mathematics education," also yielded sixteen results, only half of which were published after the year 2000. The outcomes of these database searches demonstrate a significant need for research addressing the use of educational technology for differentiation purposes in STEM education. The following section reviews empirical studies investigating the use of different educational technologies for the purposes of differentiation in STEM education.

Maeng and Bell (2015) conducted a study, discussed in a previous section of this chapter, in which one of the teacher participants demonstrated notable proficiency in providing differentiated instruction in the science classroom, using a variety of low-preparation to complex strategies; this teacher became the focus of Maeng's (2016) in-depth case study to investigate how a high school biology teacher utilized technology to facilitate differentiation in her classroom. This teacher used pre-assessments and formative assessments to identify students' needs. Technology-enhanced assessments allowed the teacher to collect information about students' understanding of content, provide timely and relevant feedback to students, and modify and plan instruction to optimize learning (Maeng, 2016). For example, as soon as students finished a warmup assignment with clickers, the teacher in this case study immediately identified questions that students had difficulty with and address these issues with the class. Clickers also allowed this teacher to use benchmark assessment data to inform decisions about which biology concepts to include in a series of stations activities for review. The use of the Internet, Smartboards, PowerPoint, and other educational technologies allowed this teacher to further differentiate by content, product, and process and provide students with choices based on their preferred learning styles (Maeng, 2016).

Colombo and Colombo (2007) explored the use of technology to address the varying learning needs of diverse learners in a middle school science class. These learners included English-language learners (ELL), students with individualized education plans (IEPs), and talented and gifted students. Specifically, these authors described how teachers used classroom blogs, podcasts, and vodcasts to differentiate learning, introduce and reinforce concepts, and extend instructional time beyond the constraints of the designated class time (Colombo & Colombo, 2007). These technologies, such as blogs and recorded lectures, allowed students to access the content from home and to view the content as many times as they want or need to process the information; these technologies also offered students a variety of modes of content presentation, such as text, audio, or video, which an appeal to students' different learning preferences.

Zheng, Warschauer, Hwang, and Collins (2014) investigated the impact of laptops and interactive science software on fifth grade students' learning, academic achievement, and interest in STEM. These students were from four culturally and linguistically diverse elementary schools participating in a one-to-one laptop program. Teachers at these schools had participated in professional development focused on technological proficiency and integrating technology into the science curriculum. These teachers were also trained to use software that featured e-Book reading passages, interactive glossaries, and virtual laboratories. There were 19 teachers and 20 students who participated in semi-structured and group interviews, and classroom observations were conducted at two of the schools. Findings showed that students' scientific comprehension and conceptualization was potentially reinforced by the virtual experimental simulations and animations and that students has access to a wider variety of sources and modes of content delivery. The technology also provided opportunities for innovative activities that would otherwise be impossible to perform, such as the creation of volcano models with various environmental parameters within a virtual laboratory. The technology offered increased access to materials that could be scaffolded to meet the needs of students with different readiness and ability levels, as well as adjusted to meet students' varying learning preferences and provide them with opportunities to employ multiple intelligences. Overall, the researchers concluded that the technology-facilitated instruction supported more individualized and differentiated instruction while also having positive impacts on students’ science achievement and motivation to pursue STEM-related careers (Zheng et al., 2014).

Research by Haelermans, Ghysels, and Prince (2015) employed digital differentiation to determine the effects on student performance second year biology class in the Netherlands. All students took pre- and post-tests for each unit, and all students used digital instructions and assignments to study the content; however, the pre-test scores of students in the treatment group were used to determine which of the three possible tracks they would follow for the week. The control group students, on the other hand, followed a single learning route. For the differentiated tracks, lessons were varied based on text complexity, pacing, and difficulty lessons to meet the needs of each student based on their pre-test scores for each unit. In this example of differentiating according to background knowledge and readiness levels, the basic concepts were the same, but each track differed in simplicity of language, pacing, and depth of content covered. Students' post-test scores served as the measure of student performance in this course. Results of this experiment showed that digital differentiation had a significant and positive effect on student performance (Haelermans et al., 2015).

Kaur, Koval, and Chaney (2017) conducted a qualitative study investigating the use of iPads to supplement math instruction. This research focused on a one-on-one math tutoring program for elementary students with learning disabilities. Specific iPad application-based activities were selected for each student based on their ability levels and needs. The ten teacher participants reflected on their experiences and completed survey at the end of the five-week time period. According to this study, the supplemental use of the iPads accommodated students' differing learning styles, provided a means of informal assessment, improved student engagement, independence, and participation, helped students develop mathematical understanding, and helped teachers provide more individualized instruction for students (Kaur et al., 2017).

Summary

As demonstrated by the studies described above, educational technology has a great deal of potential as a teaching and learning tool, but it should be employed thoughtfully and carefully. Collectively, these studies emphasize that attention should also be paid to meeting the diversified needs of our students with the use of differentiated instruction. The dynamic environment of the classroom can be made even more complex with the challenges of technology integration. As a STEM educator in a school system that is currently implementing a one-to-one technology initiative, I feel it is imperative to proactively identify ways to effectively and efficiently use this technology to greatest benefit of the students. Additionally, as a STEM educator, I have recognized the importance and necessity of differentiating instruction to reach the wide range of diverse learners in the classroom, and I also understand the importance of identifying, understanding, and addressing the challenges teachers face when using technology for the purposes of differentiation. This literature review reinforced the significance of these issues pertaining to the use of educational technology to differentiate instruction in the classroom. The aim of the current study is to investigate how teachers in STEM-related classrooms employ available educational technology to differentiate instruction and improve learning for students of all backgrounds and ability levels. This study also seeks to examine factors that influence teachers' perspectives and choices regarding the use of educational technology for differentiation purposes in STEM education.

Chapter 3

Theoretical Framework & Methodology

The purposes of this study are: 1) to examine ways high school STEM teachers employ educational technology to differentiate instruction in the classroom to improve learning for students with diverse ability levels and backgrounds, and 2) to explore challenges and opportunities associated with teachers' use of technology for differentiation purposes. This chapter will detail and justify the methods and theoretical framework of this investigation. The following questions guided this study:

1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?
2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?
    a. What specific educational technologies do STEM teachers use to differentiate instruction in their courses?
    b. What are the affordances of such technologies for differentiation?
    c. What types of challenges do high school STEM teachers face when using educational technology for differentiation?

This chapter describes the methodology that was used to conduct this research. I begin by outlining the theoretical framework that informed the data collection and analysis in this study. Next, I describe and justify the use of qualitative methods and case study design to address the research questions above. The process of data collection and data analysis are further explicated, followed by a discussion of the validity, generalizability, and limitations of this study.

Theoretical Framework

The processes involved in both teaching and learning are complex, and the integration of technology into the classroom can create an even more complex and dynamic learning environment. This integration of educational technology has the potential to assist in the transformation of learning from a one-size-fits-all model to a more differentiated and personalized experience; however, in order to effectively investigate the complexities involved with employing educational technology for differentiated instruction, a theoretical framework is needed to guide the research. According to Merriam & Tisdell (2016), the theoretical framework "forms the scaffolding or underlying structure of [the] study" (p. 2).

In the current study, Cultural-Historical Activity Theory (CHAT) (Cole, 1996; Engeström, 1987; Leont′ev, 1978; Vygotsky, 1978) provided the framework to understand how STEM teachers utilize technology for differentiation in blended learning environments, knitting together established teaching methods, differentiated instruction, and technology and unearthing the challenges experienced by teachers in doing so. CHAT served as a basis for exploring if and how STEM teachers integrate educational technology for the purposes of differentiating instruction to meet the needs of the diverse learners in their classrooms.

CHAT has gained popularity in the field of educational research "because it conceptualizes individuals and their environment as a holistic unit of analysis...and acknowledges the complexities involved in human activity in natural settings" (Yamagata-Lynch & Haudenschild, 2009, p. 508). CHAT, also referred to as activity theory, has been used as a framework to explore various facets of education, such as technology integration (Lautenbach, 2014; Lim & Hang, 2003; Y. Park, 2015; Vennebo, 2017) and the challenges teachers experience in implementing educational reform (Saka, 2007). In the current study, activity theory allowed for the analysis of a more interconnected, big picture view of the integration of educational technology to differentiate instruction.

Activity theory was originally developed in the 1920s by Russian scholars to transform the science of psychology into one "that studied human activity as an interaction-based holistic engagement between individuals and their environment" (Yamagata-Lynch, 2010, p. ix). The first model of activity theory is based on Vygotsky's (1978) work on learning through mediation; more specifically, individuals interact with mediating tools to create signs, or impressions, that aid in the meaning making process (Engeström, 2001; Vygotsky, 1978; Yamagata-Lynch & Haudenschild, 2009). According to Vygotsky (1978), consciousness was co-created through human participation in activities, where the organism and its environment interacted as components of a complex system. This concept of mediation, which involves an individual's interaction with various artifacts and tools to accomplish a goal, is represented by Vygotsky's basic mediated action triangle (see Figure 2.1, p. 17, Yamagata-Lynch, 2010). The basic mediation triangle shows the relationship between the subject (individual), mediating artifact/tool, and object involved in Vygotsky's theory. In this model, the individual is the subject, the object is the goal of the activity, and the mediating artifacts or tools include other people, prior knowledge, and physical items (Yamagata-Lynch & Haudenschild, 2009). In this theory, an individual's cultural means, the activity, and the influence of individuals' producing and using artifacts are necessary components to understanding the individuals themselves (Engeström, 2001).

Leont'ev contributed to the development of the next generation of activity theory by identifying the unit of analysis as object-oriented activity, with a clear distinction between activities and more temporary, short-term goal-directed actions; these activities are both social and cultural in nature (Yamagata-Lynch, 2010). Leont'ev shifted the focus of activity theory from individual action to include the complex interactions between the individual and their community (Engeström, 2001).

In understanding social transformations, Engeström (1999) acknowledged that socioeconomic structures, individual behavior, and human agency impact one another and cannot be separated, identifying "a need for an approach that can dialectically link the individual and the social structure" (p. 19). To illuminate the complexities of human activity and justify the need for an appropriate theory to understand these complexities, Engeström (1999) explains:

> Human activity is endlessly multifaceted, mobile, and rich in variations of content and form. It is perfectly understandable and probably necessary that the theory of activity should reflect that richness and mobility. Such a multivoiced theory should not regard internal contradictions and debates as signs of weakness; rather, they are an essential feature of the theory. (p. 20)

Instead of examining an activity from a single viewpoint, this activity system incorporates cultural, social, psychological, and institutional perspectives (Cole, Engeström, & Vasquez, 1997). Engeström incorporated the sociohistorical collective nature of mediation by including the community, rules, and division of labor to Vygotsky's basic structure of mediated action, indicating that the individual mind is not isolated from culture and society (Engeström, 1999; Yamagata-Lynch, 2007).

Engeström (1999) also emphasizes the importance of Vygotsky's idea of mediation in activity theory, arguing that the use and creation of artifacts and tools can allow humans to control their own behavior. According to Engeström (1999), these artifacts are "integral and inseparable components of human functioning," and "activity theory has the conceptual and methodological potential to be a pathbreaker in studies that help humans gain control over their own artifacts and thus over their future" (p. 29).

Subsequently, activity theory evolved to include the study of multiple interacting activity systems (Engeström, 1999; Lave & Wenger, 1991). Engeström (1999) describes society as more of a "multilayered network of interconnected activity systems" instead of a "pyramid of rigid structures dependent on a single center of power" (p. 36). Activity systems analysis has also been applied to research in which the investigator participates and intervenes in the participants' activity, changing the participants' experiences (Yamagata-Lynch, 2010). Taken altogether, activity theory acknowledges the complexities within a single activity system, as well as the complexities of the numerous activity systems that interact with and influence one another.

The impact of activity theory can be seen in various fields of research, including teaching, learning, and human-computer interaction (Engestrom & Miettinen, 1999). For example, activity theory can be applied to the study of constructivist learning environments (Jonassen & Rohrer-Murphy, 1999), such as the high school classroom. According to Jonassen and Rohrer-Murphy (1999):

> Activity cannot be understood or analyzed outside the context in which it occurs. So when analyzing human activity, we must examine not only the kinds of activities that people engage in but also who is engaging in that activity, what their goals and intentions are, what objects or products result from the activity, the rules and norms that circumscribe that activity, and the larger community in which the activity occurs. (p. 62)

The CHAT theoretical framework allows researchers to examine interactions between individuals and their natural environment during engagement in an activity of interest (Yamagata-Lynch, 2010). CHAT forms the foundation of activity systems analysis. In activity systems analysis, the unit of analysis is the human activity, and the activity triangle model is applied to study the components involved in that human activity (Yamagata-Lynch, 2010). According to Yamagata-Lynch (2007), although the activity systems approach cannot solve all the challenges involved in complex qualitative research, "it can provide an initial framework for making sense of complex data sets to find systematic implications that inform both theory and practice" (p. 453).

The current study focuses on the activity of high school STEM teachers' integration of educational technology for the purposes of differentiating instruction in the natural setting of the classroom. This technology-assisted differentiation is viewed from a CHAT perspective, taking into account the influence, interactions, and interrelatedness of various components of the activity system: the subject, community, rules, division of labor, tools, and object. This theory facilitated the investigation of the features that influence and mold these teachers' decisions and actions involved in integrating educational technology for differentiation purposes. CHAT informed interview questions and provided direction for the collection and analysis of interview and classroom observation data as the research questions guiding this study were addressed. Each component of the CHAT activity system is explained in greater detail below. Along with these explanations, I suggest some potential examples for each component as it relates to this study. These potential examples, depicted in the triangle model shown in Figure 3, are based on my own personal experiences as a high school STEM teacher working with educational technology to differentiate instruction in my classroom as well as my reading of relevant literature. It is important to note that the specific details of activity system triangles for each participant/subject were based on new understandings that evolved during data collection and analysis; additionally, the activity system triangles vary from subject to subject, or from teacher

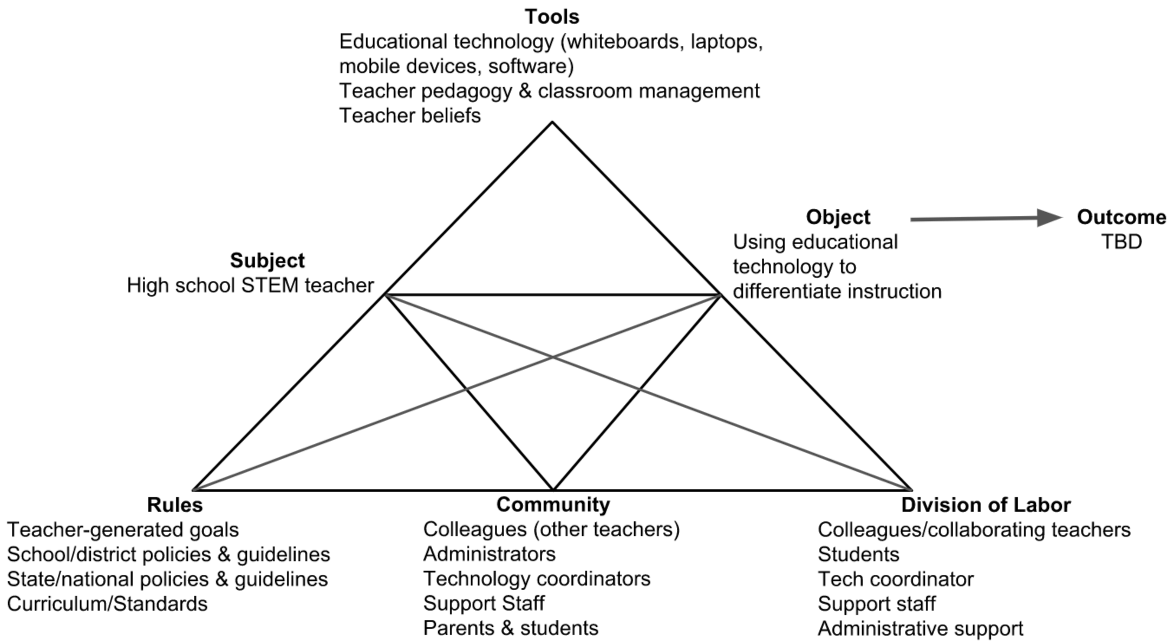

Figure 3. Triangle model of activity system. This figure illustrates the components of CHAT that may exist within the activity system of a high school STEM teacher's use of educational technology to differentiate instruction.

to teacher, as the aspects of each activity system interact in different ways, influencing the behaviors of the subjects and other individuals within the community of their activity system.

To begin, I will elucidate the concept of the "object," sometimes also referred to as the "objective," of an activity system. Yamagata-Lynch (2010) explains that some debate or confusion surrounds the meaning of the "object" within the theory of CHAT due to translational issues and multiple meanings of the Russian "object." More specifically, this term "has been used interchangeably to refer to the goal of an activity, the motives for participating in an activity, and material products that participants try to gain through an activity" (Yamagata-Lynch, 2010, p. 17). In this study, a potential object or goal of the activity system of interest is enhanced student learning through differentiated instruction.

Another tenet of the activity system is the "subject." The subject of an activity system is defined as "the individual or individuals engaged in the activity" (Yamagata-Lynch, 2010, p. 16). According to Jonassen and Rohrer-Murphy (1999), it is imperative to understand the subject, which includes understanding their motivations and beliefs. Since the purpose of this study is to examine the engagement of high school STEM teachers in the activity of differentiating instruction in the classroom, high school STEM teachers are the subjects of the activity system of interest. In-depth data collection and analysis is needed to fully understand these subjects and their perspectives.

A third component of activity theory is the "community." Engström (2001) describes one of the principles of activity theory as "multi-voicedness," referring to "a community of multiple points of view, traditions and interests" that exists within an activity system (p. 136). Subjects typically do not act in isolation; in other words, the subject will often act with the support of their surrounding community or others with whom the work or activity is shared (Engeström, 2001). Jonassen and Rohrer-Murphy (1999) define the community as "the interdependent aggregate…who share (at least to some degree) a set of social meanings" (p. 64). The community of the current study's activity system of interest may include the high school STEM teachers' colleagues, administrators, technology coordinators, and other support staff; students and their parents may also be considered as part of this community as well.

The community described above mediates and negotiates certain formal and informal rules that guide and regulate activity, affecting the beliefs, functionality, and interactions within that community (Jonassen & Rohrer-Murphy, 1999). Rules are defined by Yamagata-Lynch (2007) as constructs that, to some extent, enable or control the occurrences of activities. These rules may be generated from a variety of sources, such as the subjects themselves or others with greater authority and power. In the examination of high school STEM teachers' integration of educational technology for differentiation purposes, the rules may be developed by the teachers themselves, by school- or district-level administration, or even by state and national governments. These rules may include attaining certain achievement goals, such as students' scores on standards-based tests, or abiding by particular guidelines for teaching practice within the classroom, such as providing accommodations for students' individual education plans (IEPs) or following other school regulations and policy. The specific rules and norms that guide and influence the activity systems in this study were determined as data was collected and analyzed during the course of the research.

Within the community, different positions are created for the participants involved in an activity; the different positions are called the division of labor (Engeström, 2001). Yamagata-Lynch and Haudenschild (2009) describe this division of labor as "the shared participation responsibilities in the activity determined by the community" (p. 508). The division of labor component of CHAT in this study's activity systems may consist of high school STEM teachers' peers, administration, technology support staff, and others who share responsibility and take part in the activity of integrating educational technology in the classroom to differentiate instruction.

Understanding the mediating tools, or artifacts, is yet another vital element in the use of activity theory to analyze an activity. From a CHAT perspective, tools are artifacts that participants, or subjects, have deemed valuable for engaging in a certain activity in hopes of accomplishing an object or goal (Yamagata-Lynch, 2010). These tools can be physical or mental in nature, as long as they are used in pursuit of the activity system's object (Jonassen & Rohrer-Murphy, 1999). In the current study, the tools may include the course curriculum or standards, textbooks, and educational technology, such as interactive whiteboards, laptops, tablets, mobile devices, and software. Educational technology, which is of particular significance in this study, can act as a tool or mediating artifact in several ways; for example, it can be used as an information stream, an enabler of communication and collaboration, an information transformation tool, or a professionalization tool (Amory, 2014). Additionally, teacher pedagogy, classroom management strategies, and other intangible or cognitive items can serve as tools to accomplish the object or goal of differentiating instruction to improve the learning of all students within the classroom. Alternatively, differentiated instruction, which has been portrayed up to this point as part of the object, may actually present itself as more of a tool used to reach the goal, or object, of improving student learning once data has been collected and analyzed.

In activity theory, outcomes are the consequences that result from the subject's actions in pursuit of the object of the activity; outcomes of one activity can positively or negatively influence subjects' participation in subsequent activities (Yamagata-Lynch & Haudenschild, 2009). The collection and analysis of subject interviews and classroom observation data provides insight into the outcomes, or end results, of the activity of interest: teaching high school STEM-related courses with a focus on teachers' use of educational technology to differentiate instruction.

Contradictions have a central role as sources of development and change in an activity (Engeström, 2001). Tensions are "pressures influenced by systemic contradictions that subjects encounter while participating in an activity" (Yamagata-Lynch, 2010, p. 143); these contradictions and tensions can influence interactions between activity system components, affecting the subject's ability to procure the object by either facilitating or impeding the subject's efforts (Yamagata-Lynch, 2010). For example, the introduction of changes to rules, the community, or division of labor can affect the availability of certain tools and how they can be used in the pursuit of the object of an activity system. A potential contradiction might exist, for instance, if a teacher plans to employ a lesson involving student access to certain websites or other specific technologies but then discovers there are restrictions in place and those websites or technologies are not available to the students. Another potential contradiction might exist if teachers struggle to meet the expectations of parents or administration, or even their own personal educational goals, due to limited time and resources.

Engeström (1987) identified four layers, or levels, of contradictions within the human activity system. Primary contradictions are defined as "inner conflict between exchange value and use value within each corner of the triangle of activity," or the double nature that exists within the central activity's constituent components (p. 102-103). Engeström (1987) provides an example of a primary contradiction in the central activity of physicians' use of medication; in this activity, the medication is an instrument, or tool, that has a dual nature as both a useful preparation for treating patients as well as a manufactured commodity that has a price and is sold for a profit. Secondary contradictions exist between the central activity's constituent components. In the example of physicians' activity, a secondary contradiction could exist between the object, patients' complex problems and symptoms to be treated, and the available tools, the instruments and medications that are currently available. Tertiary contradictions occur when the object or motive of a more advanced form of the central activity is introduced, conflicting with the object or motive of the original central activity. In Engeström's (1987) physician example, a tertiary contradiction could arise when physicians are ordered to employ a new procedure, but the physicians may resist or prefer to continue using the original form of the procedure. Quaternary contradictions are between central activities and their linked neighbor, or adjacent, activities. The links between the central and adjacent activities may lie within common objects and outcomes of these activities, or the neighbor activities may produce key instruments or tools for the central activity. The neighbor activities may also influence the subject of the central activity, such as in the case of the subject's education and schooling. Finally, adjacent activities may also be involved in the production of the rules of the central activity, like legislation and administration (Engeström, 1987).

Some researchers criticize activity theory, naming issues with the complexities and difficulties involved in understanding and applying activity systems analysis as a theoretical framework (Yamagata-Lynch, 2010). Toomela's criticisms centered around the belief that, by focusing on observable human activities as the unit of study, activity theory was lacking recognition of human cognitive and semiotic processes (Toomela, 2000, 2008; Yamagata-Lynch, 2010). In another critique of CHAT, Nardi (1996) describes an experience where an editor claimed activity theory was too complex for readers to understand. Yamagata-Lynch (2010), on the other hand, claims that if researchers possess and communicate a thorough understanding of this theory, the complexity of CHAT provides opportunities for richer, more in-depth investigation of experiences in a real-world context. A third criticism made by Roschelle (Roschelle, 1998) claims that activity theory cannot inform practice because this theory does not result in generalizable claims; however, the goal of case studies is to develop a deeper understanding of a specific case (or group of cases), which may or may not be generalizable to other cases (Stake, 1995).

Qualitative Methodology

Qualitative research methodology was employed to allow for in-depth investigation of the research questions above. Qualitative research studies involve “the search for meaning and understanding, the researcher as the primary instrument of data collection and analysis, an inductive investigative strategy, and the end product being richly descriptive" (Merriam & Tisdell, 2016, p. 37). Essentially, understanding others' experiences and how they make sense of the world lie at the heart of qualitative research (Merriam & Tisdell, 2016). Teaching and learning are complex, dynamic processes, and differentiating instruction and integrating educational technology in the classroom generate additional layers of complexity. Qualitative analysis allows the researcher to explore the intersection of these issues on a deeper level, within the context of high school STEM classrooms, gaining both emic and etic perspectives through the use of interviews and observations. The methods employed in this qualitative study – interviews and classroom observations – provide both an outsiders and insiders perspective of the phenomenon of interest (high school STEM teachers' use of educational technology for differentiation purposes in the classroom). These qualitative methods allow for the in-depth, detailed data collection and analysis that is needed to develop an understanding of the subjects (high school STEM teachers), as well as the other activity system components mentioned in the above discussion of CHAT.

Design of Study: Case Study

A collective case study approach was chosen for this study in order to conduct a more thorough and detailed examination of high school STEM teachers' use of educational technology to differentiate instruction. Case study involves the study of an issue within one or more bounded systems, or cases, through "detailed, in-depth data collection involving multiple sources of information" (Creswell, 2007, p. 73). According to Yin (1994), "case studies are the preferred strategy when "how" or "why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context" p. 1. The current study meets all of these criteria: the research questions center around "how" and "why" teachers are using educational technology for differentiation purposes in the high school STEM classroom; I, the researcher, do not have control over the events that occur within the bounded systems of each case; and the phenomenon of interest (teaching high school STEM-related courses and the use of educational technology for differentiation purposes) is taking place within the real-life context of the high school STEM classroom.

Compared to quantitative or positivist approaches, case study's advantages lie in a greater depth of analysis; this depth can be viewed as "empirical completeness and natural wholeness or as conceptual richness and theoretical consistency," and can also provide a more internally valid account of the phenomenon (Blatter, 2008). Creswell (2007) explains that a collective case study, also called multiple case study, is a study that focuses on one issue or concern, while investigating and illustrating the issue using multiple cases. The cases within this collective case study can also be classified as instrumental; in instrumental case study, the goal is not to understand each individual case, but to use the cases to understand an issue or concern (Flick, 2014; Stake, 1995). Each teacher participant in this collective case study will be considered a case, with the goal of understanding the issue of educational technology use for differentiation rather than understanding each specific teacher (Stake, 1995). More specifically, in this multi-site case study, high school STEM teachers were interviewed and observed to better understand the use of educational technology in the classroom to differentiate instruction. This investigation is considered multi-site because the teacher participants were from more than one school, and interviews and observations were conducted at these two different locations. Multiple cases can improve the validity of a case study, providing further insight and allowing the researcher to compare and contrast the perspectives, decisions, and actions of the study's participants.

Role of the Researcher

As stated above, in qualitative research, which is focused on investigating meaning within context, the researcher is the primary data collection and analysis instrument (Merriam & Tisdell, 2016). Merriam and Tisdell (2016) argue that humans are best suited for the data collection and analysis methods of qualitative inquiry since they are responsive, adaptive, and able to sense underlying meaning. As the research instrument, the researcher must possess and sharpen the skills needed to observe others' behavior and participate in face-to-face interviews with research participants (Denzin & Lincoln, 2000). In qualitative studies, the researcher must become a sort of quilt maker or *bricoleur,* sometimes referred to as a Jack of all trades, developing or piecing together new tools or techniques (Denzin & Lincoln, 2000). As the research instrument, the researcher employs multiple strategies and systematizes pieces of data to construct a deeper understanding of the topic of study. This allows the researcher to develop richer, deeper understandings; however, the researcher's pathway to constructing these understandings may not be clearly set in advance (Denzin & Lincoln, 2000). Considering the complexity of skills and amount of time demanded as the qualitative research instrument, the role of the researcher can be viewed as challenging, time-intensive, and sometimes even overwhelming.

The role of the researcher in qualitative inquiry is not without criticism. According to Yin (1994), many case study investigators have been accused of allowing ambiguous or questionable evidence or biased views to impact the findings and conclusions of their research, although no research strategy is truly free from the potential of bias; therefore, "every case study investigator must work hard to report all evidence fairly" (Yin, 1994, p. 10). Merriam and Tisdell (2016) explain that the researcher instrument, being human, has certain biases and shortcomings that can impact a study, but, instead of attempting to eliminate these subjectivities, the researcher must identify and monitor them while providing clarity and transparency when describing their choices and actions involving data collection and analysis.

Emic and Etic Perspectives

When conducting observations, collecting and analyzing data, and making other decisions throughout the research process, researchers may be guided by their own values, referred to as an etic perspective, or by the values of the observed, referred to as an emic perspective (Vidich & Lyman, 2000). Creswell (2007) describes "emic" as the reporting and writing from the research participants' perspectives. An emic perspective can also be thought of as an "insider's perspective" (Merriam & Tisdell, 2016, p. 16). Summaries and excerpts of participants' interview data infuse an emic voice into the study. Additionally, I am also an educator who is currently attempting to augment my own differentiation practices using educational technology in my own STEM-related courses, providing additional insider perspective throughout this exploration.

An etic approach entails reporting and writing from the personal perspective of the researcher, or from an "outsider's view" (Creswell, 2007; Merriam & Tisdell, 2016, p. 16). The etic perspective in this particular case study provides information as to how I, the researcher, perceived the participants. Even though I am a fellow STEM teacher, I am considered as somewhat of an outsider while researching other teachers' practices during interviews and observations, as I would not typically be present as a part of their normal classroom activities and no two teachers or classrooms are exactly the same. Furthermore, constructivism pervades the etic perspective of this study as I provide the narrative of my knowledge construction as the researcher studying these cases and issues. These intertwined emic and etic perspectives allow for analysis of this case study that is in-depth, meaningful, and relevant.

Sites and Participants

Sites

Purposeful convenience sampling (Patton, 2002) was used in the selection of the sites and participants. According to Patton (2002), purposeful sampling involves selecting cases "because they are "information rich" and illuminative, that is, they offer useful manifestations of the phenomenon of interest," with the intention of gaining insight about the phenomenon rather than the ability to generalize from sample to population (p. 40). This sampling was also considered to be convenience sampling because certain resources, such as time, funds, and availability of participants will be limited; for example, with consideration to available STEM teachers and travel time and expenses, the researcher had access to participants located within an appropriate drivable distance who had given their consent for this study (Flick, 2014).

My goal was to find two schools that were currently implementing a one-to-one technology initiative since that would ensure teachers and students had access to educational technology in the classroom. I also sought schools with teachers who were teaching high school level STEM-related courses because this study investigates STEM teachers' use of educational technology to differentiate instruction in the classroom. While I was looking for schools that would allow me to find participants that met these criteria, I also wanted to look at schools from two different districts to explore potential differences in factors that affect high school STEM teachers' use of educational technology to differentiate instruction. The final criterion was that the districts and schools would be willing to participate in a semester-long study of how teachers employed educational technology to differentiate instruction in their classrooms.

The sites chosen for this study are two local schools, Actin High School of Actin City Schools and Myosin Junior High School from Myosin City Schools; both of these districts are currently implementing one-to-one laptop initiatives, where every student has access to Internet-enabled devices to use during class. These school districts were chosen because they met all of the above criteria. Myosin City Schools began piloting their one-to-one program during the 2014-2015 school year, and, at the time of this study, Myosin Junior High students have each been assigned their own laptops to use at school and at home for the third year. Actin City Schools began piloting their one-to-one program during the 2016-2017 school year. At the time of this study, only selected classrooms at Actin High School had classroom sets of Chromebooks (laptops) to use, but students at Actin High School were not assigned their own devices to take home. The goal of the one-to-one initiative at Actin City Schools was to eventually have classroom sets of devices in every classroom, grades two through twelve, in the district.

As outlined earlier, this study was a multi-case study, and I chose to conduct research at Actin High School and Myosin Junior High School. Actin High School contains grades nine through twelve, while Myosin Junior High School contains grades eight and nine. There were no interested or willing teacher participants who met the above criteria from Myosin High School, which contains grades ten through twelve. Consequently, I focused on participants at Myosin Junior High School who taught ninth grade STEM-related courses, which are considered high school courses, maintaining the focus on high school STEM teachers and allowing for comparison between the cases from Myosin City Schools and Actin City Schools. There are differences between the selected districts and schools which must be taken into consideration.

The two districts were at different points of their one-to-one program implementation, as previously described. Also, students at Myosin Junior High School carry their laptops with them from class to class and home at the end of the day, while students at Actin High School currently only have access to Chromebooks while they are in select classes. For the Actin High School participants in this study, I only considered teachers who had classroom sets of Chromebooks to ensure that the teachers and students had access to technology during class time that was comparable to the technology access of the Myosin Junior High School teachers and students. Table 1 outlines the student and teacher demographics of the districts and schools included in this study, as reported by the Tennessee Department of Education (n.d.).

Participants

Participants for this study were selected from educators who were teaching high school level STEM-related courses at the two chosen schools in districts implementing one-to-one technology initiatives, as stated above. There were a total of seven participants in this study. Four teachers were selected from Actin High School, and three teachers were selected from Myosin Junior High School. Table 2 lists each participant, number of years of teaching experience, subjects taught, and school where they were employed during the time of the study. Each teacher participated in three semi-structured interviews, and two classroom observations were also conducted for each teacher – after the first and second interviews. These observations allowed me to gather information about the environment of the classroom and to observe the integration of educational technology, focusing on how it was used to differentiate instruction, during normal class activities. The observation data was also used to help formulate questions in subsequent interviews.

Table 1

Comparison of Student Demographics: 2016-2017 Data

Student Ethnicity & Demographics	**Actin City Schools**	**Actin High School**	**Myosin City Schools**	**Myosin Junior High School**
Race				
White	63.9%	64.1%	86.5%	87.5%
Black or African-American	21.7%	26.5%	5.0%	5.8%
Hispanic or Latino	11.5%	6.8%	5.2%	3.6%
Asian	1.9%	1.7%	2.9%	2.5%
Native American or Alaskan	0.6%			
Demographics				
English Language Learners	4.3%	1.6%	3.0%	1.6%
Economically Disadvantaged	27.9%	19.5%	17.6%	15.4%
Students with Disabilities	13.0%	10.2%	12.8%	11.4%
Total Student Enrollment	2,013	635	5,225	830

Table 2

Teacher Participants

Participant	Years Experience	Current Subject(s)	School
Camille	7	Algebra I, Algebra II	Actin High
Jemma	15	Algebra II	Actin High
Simon	22	Algebra I	Actin High
Syrus	19	STEM	Actin High
Austin	11	STEM	Myosin Junior High
Libba	8	Biology	Myosin Junior High
Marybeth	22	Biology	Myosin Junior High

The CHAT framework informed the selection of high school STEM teacher participants because the components of the high school STEM classroom activity system, including the STEM teacher as the subject, must be considered as interconnected and vital to understanding the activity system as a whole; this CHAT perspective provided a deeper understanding of STEM teachers' perspectives and use of educational technology to differentiate instruction in the classroom. As stated previously, most of current literature surrounding differentiated instruction focuses on elementary and middle schools (Benjamin, 2005; Maeng, 2016; Maeng & Bell, 2015), so this study investigated differentiation at the high school level. The focus of STEM-related classes was chosen due to increasing interest in STEM education (Chesky & Wolfmeyer, 2015; National Research Council, 2012). There is a need to understand how differentiated instruction is implemented in high school STEM classes, and, with the increased availability of educational technology, there is also a need to investigate the current and potential roles that technology may play in differentiation in these classrooms. Each participant's background and the findings from interviews and observations are described in detail in Chapter 4.

Data Collection

After sites were chosen, the study proposal was submitted for approval by the University of Tennessee's Institutional Review Board (IRB). After IRB approval, the data collection process began for this study. Case study often involves the multiple different data sources, including interviews, field observations, and documents (Flick, 2014; Stake, 1995). In the current study, data was collected by conducting interviews and classroom observations. When conducting a case study that involves interviews and observations, gaining access to the sites of interest must be taken into consideration. Prior to data collection, signed approval was obtained from the administrators at the school systems to be included in the study, and signed consent was obtained from each of the teacher participants. The interviews were conducted in the teachers' classrooms at times mutually agreed upon by the interviewer and the interviewee. The observations took place during the regular class time in the STEM teachers' classrooms while class was being conducted.

Since the theoretical framework forms the foundation of a study, the theoretical framework should be considered in all elements of a study, including data collection (Merriam & Tisdell, 2016). Therefore, activity theory guided the methods of data collection and data analysis chosen for the current research. This theory was utilized in the development of the interview questions, as well as used to provide direction in the collection of classroom observation data.

Interviews

Principal uses of case study include obtaining the descriptions and interpretations of others, as qualitative research involves discovering and portraying various views and perspectives of a case (Stake, 1995). According to Stake (1995), interviewing is the primary route to accessing these "multiple realities" (p. 64). In the current study, individual semi-structured interviews were conducted at locations agreed upon the interviewer and interviewees. Semi-structured interviews employ written interview guides composed of open-ended questions, while allowing the interviewer the flexibility of asking questions based on the interviewees' responses (Ayres, 2008). The use of semi-structured interviews enables the researcher to gain first-hand personal accounts of experiences, choices, and feelings from the participants' perspectives. Merriam and Tisdell (2016) describe semi-structured interviews as flexibly guided by a list of topics or questions to be explored, stating "this format allows the researcher to respond to the situation at hand, to the emerging worldview of the respondent, and to new ideas on the topic" (p. 111).

Interviews were audio recorded, and the data was later transcribed and coded to identify relevant and significant themes relating to the teachers' integration of new educational technology for the purposes of differentiating instruction in the classroom. Three semi-structured interviews were conducted for each participant over the data collection time period (January to May 2018). The initial interview consisted of questions related to the participants' backgrounds, as well as questions that allowed the teachers to communicate and elaborate on their teaching, differentiation, and technology-related experiences; additionally, the initial interview allowed the interviewees to acclimate to the interviewer and the interview process. Questions also specifically addressed aspects of the teachers' choices and perspectives related to the integration of educational technology for differentiation purposes in STEM-related classrooms. This additional data allowed for increased depth of understanding from the teachers' perspectives, which were then triangulated with the information from observations and previous interviews

(Denzin & Lincoln, 2000; Flick, 2014). The data obtained from the initial/earlier interviews and observations was used to develop interview questions to be used during subsequent interviews. The interview questions are listed in the appendix of this dissertation.

Classroom Observations

Classroom observations were also conducted to allow for the collection of richer data and triangulation, which is the use of a combination of varied methods and data sources (Creswell, 2007; Flick, 2014). Observations take place in a phenomenon's natural setting and provide data that "represent a firsthand encounter with the phenomenon of interest rather than a secondhand account of the world obtained in an interview" (Merriam & Tisdell, 2016, p. 137). Merriam and Tisdell (2016) specify multiple reasons for gathering observational data. For example, from an outsider's perspective, the researcher may notice things that have become routine or overlooked by the participant. Observations can also be used to triangulate findings from interviews and other data collection methods, as well as to gain knowledge of context and other incidents that may provide reference points for subsequent interviews. These overt observations took place in the natural environment of the classroom, and the observer attempted to interfere as little as possible with the normal activities and occurrences in the classroom (Flick, 2014). A total of two observations were conducted for each teacher to provide sufficient. Field notes were taken to collect data on the teachers' engagement in the activity of teaching, as well as on their use of educational technology to differentiate instruction. Although there was flexibility in the note-taking process, the components of Cultural-Historical Activity Theory (CHAT) were used to guide the observations as well as the analysis of the field notes.

Recursive Reflexivity

A researcher's journal was maintained to incorporate reflexivity into the study and to detail each step of the research process. Flick (2014) defines reflexivity as "a concept of research which refers to acknowledging the input of the researchers in actively co-constructing the situation which they want to study," and how these insights can be used to assist in the interpretation of the data (p. 542). By integrating reflexivity, the researcher "is conscious of the biases, values, and experiences that he or she brings to a qualitative research study" (Creswell, 2007, p. 243). This journal also provides transparency by allowing readers to better understand how the study was conducted. Regularly writing in this researcher's journal throughout the entire study and reviewing prior journal entries provided the recursive nature that allowed me to continuously reflect upon and critique the research process and interpretation and representation of data and findings. By committing to this practice of recursive reflexivity, the criticality and integrity of the study is reinforced, while providing transparency of choices and decisions made throughout the process (Whittemore, Chase, & Mandle, 2001).

Data Analysis and Coding

The interview transcripts and observation field note data were imported into NVivo, a qualitative data analysis software program, for further analysis and coding. In qualitative analysis, a code can be defined as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2009, p. 3). The process of coding, therefore, involves labeling and categorizing data by assigning codes to selected portions of data during the first step of analysis (Flick, 2014). Employing a provisional coding approach (Saldaña, 2009), the CHAT theoretical framework was used to create *a priori* codes for use during the coding process. Each individual case was coded first as the within-case analysis (Creswell, 2007; Merriam & Tisdell, 2016). During data analysis, as additional codes were discovered, they were added to the list of *a priori* codes as needed. After the individual cases were analyzed and reported using the CHAT framework, a cross-case analysis was performed to examine themes across cases for commonalities and variances to address the research questions of this study (Creswell, 2007; Merriam & Tisdell, 2016).

The final coding scheme in this study consisted of the following CHAT components: community, division of labor, object (goals and motivation), outcome, rules, subject, tools, and tensions/contradictions. As the coding process was performed, the rules were subdivided into the following codes: district & school policies, state standards, state testing, and teacher-generated goals. The subject codes were subdivided into teacher background, teacher perspectives, and teacher wishes for differentiated instruction. Tools were subdivided into differentiated instruction, teacher beliefs, teacher pedagogy, and technology.

Trustworthiness, Rigor and Authenticity

Merriam and Tisdell (2016) describe validity and reliability of qualitative research in terms of trustworthiness and rigor, arguing that "all research is concerned with producing valid and reliable knowledge in an ethical manner" (p. 237). While statistical studies may group together a greater number of dissimilar cases to attain larger sample sizes, running the risk of "conceptual stretching," case studies can provide increased validity over a smaller number of cases (George & Bennett, 2005). The participants in this case study, high school STEM teachers, are practitioners in the field of secondary education, and "being able to trust research results is especially important to professionals in applied fields because practitioners intervene in people's lives" (Merriam & Tisdell, 2016, p. 237). The validity of this qualitative study lies in the appropriateness and justification of the chosen methodologies and methods and in the reasoning and clarity of the research process, findings, and conclusions (Crotty, 1998).

The inclusion of multiple cases within a study strengthens the validity and stability of the findings and enhances the validity of the research (Merriam & Tisdell, 2016). The findings of multiple case studies are often considered to be more compelling than single case studies, adding to the robustness of the overall study (Yin, 1994). A total of seven STEM teachers from two different school systems were interviewed and observed. The data was first explored using a within-case analysis approach, followed by a cross-case analysis approach to identify common themes across all cases (Creswell, 2007). According to Merriam and Tisdell's (2016) description of within-case analysis, "each case if first treated as a comprehensive case in and of itself. Data are gathered so the researcher can learn as much as possible about the contextual variables that might have a bearing on the case" (p. 234). In this study, the interview and classroom observation data for each case (teacher participant) was individually and separately coded and analyzed. After completion of the within-case analyses, cross-case analysis was performed to look for commonalities and differences in the codes and themes across all cases (Merriam & Tisdell, 2016; Yin, 1994). Additionally, prolonged engagement, member checks, triangulation of data, and an audit trail were used to ensure the rigor, trustworthiness, and authenticity of the research conducted in this study. Each of these strategies is discussed below.

Prolonged Engagement

Qualitative design demands prolonged engagement, where the researcher is present in the field, collecting data over an extended period of time (Denzin & Lincoln, 2000; Morse, 2015). The practice of prolonged engagement improves the credibility of a qualitative study. By investing sufficient time to build trust with the study's participants, the researcher is likely to gain more in-depth, honest, and real data from interviews and observations (Davis, 1992). This prolonged engagement also provides opportunities to collect multiple sources of data that contribute to the ability to triangulate data during analysis. In the current study, the researcher practiced prolonged engagement by conducting three interviews and two observations with each of the teacher participants over the course of approximately five months.

Member Checks

Member checks, also called communicative validation or respondent validation, were performed to increase the validity of the study (Creswell, 2007; Flick, 2014). Lincoln and Guba (1985) consider member checking to be "the most critical technique for establishing credibility" (p. 314). To accomplish this, interview transcripts were sent to each individual participant for review, with the option for participants to add comments, provide clarification, or correct any mistakes in the transcripts if they feel their views are not accurately represented. Additional member checking was conducted with preliminary analysis, allowing the participants to confirm the accuracy of this step of the analysis process. These practices specifically enhance the credibility and authenticity of the study by improving the accuracy and credibility of interpretations of the participants' perspectives and meanings (Creswell, 2007; Whittemore et al., 2001).

Triangulation of Data

Triangulation involves the use of a combination of varied methods and sources of data to study a single issue (Creswell, 2007; Flick, 2014). The process of triangulation "involves corroborating evidence from different sources to shed light on a theme or perspective" (Creswell, 2007, p. 208). Stake (1995) explains that triangulation is used by researchers to substantiate interpretations and clarify the meanings of those interpretations. Triangulation can involve the use of different methods or sources aimed at gaining the same information (such as interviews, documents, and observations) or a single type of source with multiple respondents (Davis, 1992). In this study, data was collected using interviews and classroom observations. The credibility and validity of the study is strengthened by analyzing the themes and codes across these multiple data sources and during the cross-case analysis. The data from interviews was coded, analyzed, and used to inform future interview protocols. The data from classroom observations was also coded, analyzed, and also used to inform future interview protocols. To perform triangulation, the data from the classroom observations and interviews were compared to one another for each participant to provide further insight and substantiation of the interpretations of the data. I searched for themes and codes that existed within these multiple data sources for each participant, and then I also searched for similarities and differences in these themes and codes between the participants in the cross-case analysis.

Audit Trail

According to Merriam and Tisdell, "an audit trail in a qualitative study describes in detail how data were collected, how categories were derived, and how decisions were made throughout the inquiry" (p. 252). The researcher's journal was used to record the thought processes, decision-making, and course of action throughout this study. Additionally, interactions with the data were recorded during the analysis and interpretation processes. The audit trail provides transparency of the research process and allow readers to authenticate the findings of this study.

Generalizability

Case study research is advantageous because it can provide rich, in-depth data and analysis, but there are also disadvantages to case study regarding issues with generalization (Creswell, 2007; Flick, 2014; George & Bennett, 2005). Generalization in the qualitative research paradigm refers to the transferability of research findings and implications to other situations (Flick, 2014). According to Flick (2014), concentration on a single case can lead to problems with decreased generalizability; however, this problem can be addressed by conducting a multiple case study, as employed in the current study. Since each teacher, classroom, and school is unique, the findings of this study may not be entirely generalizable to every instance of technology integration for the purposes of differentiation in the classroom. For example, schools have varying class sizes and accessibility to resources, such as computers and wireless Internet, and teachers have varying levels of comfort and experience with differentiated instruction and with integrating educational technology in the classroom. The implications of this study, however, may allow other educators to approach the adoption and use of new educational technologies for differentiating instruction from a more informed perspective. This research provides an in-depth account of STEM teachers' choices and experiences with differentiating instruction using educational technology, which may add to the current understanding and discussion about educational technology and differentiation and potentially provide a basis for anticipating and preparing for similar situations in other schools and classrooms.

Limitations

This study was limited by various factors, including time, resources, and accessibility to sites and participants. For example, conducting multiple case studies requires extensive time for data collection in the field, as well for data analysis in within-case and cross-case analysis. (Stake, 1995; Yin, 1994). Additionally, managing the large volume of data produced in a multiple case study can prove to be quite challenging (Merriam & Tisdell, 2016). Limitations also exist in relation to the self-reported data of teacher participants during interviews; findings may be limited by the level of honesty, detail, and depth of participants' responses during interviews, which could be due to a variety of reasons. The qualitative nature may be viewed by some as potentially limiting the validity and generalizability (Yin, 1994), but these issues are addressed by member checks, triangulation, and detailed record-keeping and transparency in data collection and analysis methods, as described above. The researcher collecting and analyzing the data also holds a position as a high school science teacher employed at Actin High School, which could be viewed as a source of bias and another potential limitation. This question of bias is addressed in the section titled "Role of the Researcher."

Conclusions

A multi-case study approach was employed to achieve the goals of this study, which include investigating how high school STEM teachers employ educational technology to differentiate instruction in the classroom and examining the factors that may impact these teachers' perspectives and use of educational technology to meet the needs of diverse learners. During this study, semi-structured interviews and classroom observations were conducted to collect data for each participant. Data analysis began during the data collection process and continued until all the collected data had been analyzed first using within-case analysis followed by cross-case analysis, as described above. Multiple verification methods were employed to ensure the rigor, authenticity, and trustworthiness of the data; these verification methods include prolonged engagement, member checks, data triangulation, and an audit trail. The results of this study will be described in Chapter 4.

Chapter 4

Analysis and Findings

This multi-site case study explores how high school STEM teachers utilize educational technology to differentiate instruction in their classrooms, their perspectives on the use of educational technology to reach diverse learners in the classroom, and the factors that affect their choices related to use educational technology for differentiation. This study was designed to address the following research questions:

1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?
2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?
    a. What specific educational technologies do STEM teachers use to differentiate instruction in their courses?
    b. What are the affordances of such technologies for differentiation?
    c. What types of challenges do high school STEM teachers face when using educational technology for differentiation?

The analysis of qualitative data and themes are detailed in this chapter. First, each teacher participant is presented as a singular case using activity theory as an analytical lens. At the end of this chapter, cross-case findings are presented for the participants from Actin High School and from Myosin Junior High School, using the research questions above as a lens to explore these high school STEM teachers' perspectives and use of educational technology for differentiation purposes in the classroom.

Case 1: Camille

Professional Background and Present Experience

Camille is a math teacher at Actin High School. Her highest level of education is a Master of Science in Secondary Math Education, and she has seven years of teaching experience, including Pre-Algebra, Algebra I, Algebra II, Geometry, and 8th grade Math. During the 2071-2018 school year, Camille taught Algebra I, Algebra II, and Geometry. The school year during which this research was conducted (2017-2018) was Camille's second year using a classroom set of Chromebooks in her classes.

According to Camille, STEM education involves "thinking about the world through the eyes of science, technology, engineering, and math" (1st interview, January 2018). She was attracted to teaching STEM-related courses because, in addition to the logical aspect of mathematics, Camille enjoyed helping students explore the problem-solving nature of mathematics. She explained how even if there is a single correct answer to a mathematics problem, there may be several different paths to get to that correct answer. During the first interview, Camille stated:

> I just like how logical math is. I like how there is always a right or wrong answer, but it also lends itself to having multiple paths to get there. There's lots of different ways that you could work any different problem or consider many different problems so I like that aspect of it, but, at the end of the day, you know if you're right or not. You know if you're on the right track and if what you're doing makes sense, and I think math helps you make more sense of some things in the world. I see that it is a very clear indicator between those that don't maybe understand math concepts as well and not just solving equations but can think logically. (January 2018)

Camille integrated her passion for problem-solving, creativity, and logical thinking into her own teaching practices and encouraged students to explore and improve their own skills related to these cognitive areas.

Activity Systems Analysis: Camille

Subject and object. As previously stated, Cultural-Historical Activity Theory was employed to interpret the data from interviews and classroom observations and to analyze the factors and contradictions affecting each subject's ability to engage in the activity. In the activity systems analysis, the teachers are the subjects who are engaged in the activity of teaching STEM-related courses, and the focus of this study is on the use of educational technology to differentiate instruction during teachers' engagement in this activity. Figure 4 below provides a graphic summary of the activity system in Case 1. The subject of the activity system in this case was Camille. Camille's goals and motives, the object of this activity system, included helping students learn valuable mathematical and problem-solving skills and master the content outlined in the state standards. Camille stated:

> I'm going to consider the next set of courses that they are going to take so I'm going to cover maybe more in-depth or add some more nuances to what we're learning so that they're prepared for precalculus, or, if they're going on to a college level course, they're prepared for those things. (1st interview, January 2018)

Camille also aimed to prepare her students for life after high school, both academically and behaviorally. She wanted her students to build perseverance and motivation, developing an understanding of how they learn best and how they can use this understanding to achieve their own goals. Camille also wanted students to learn to work collaboratively with others to accomplish a common objective.

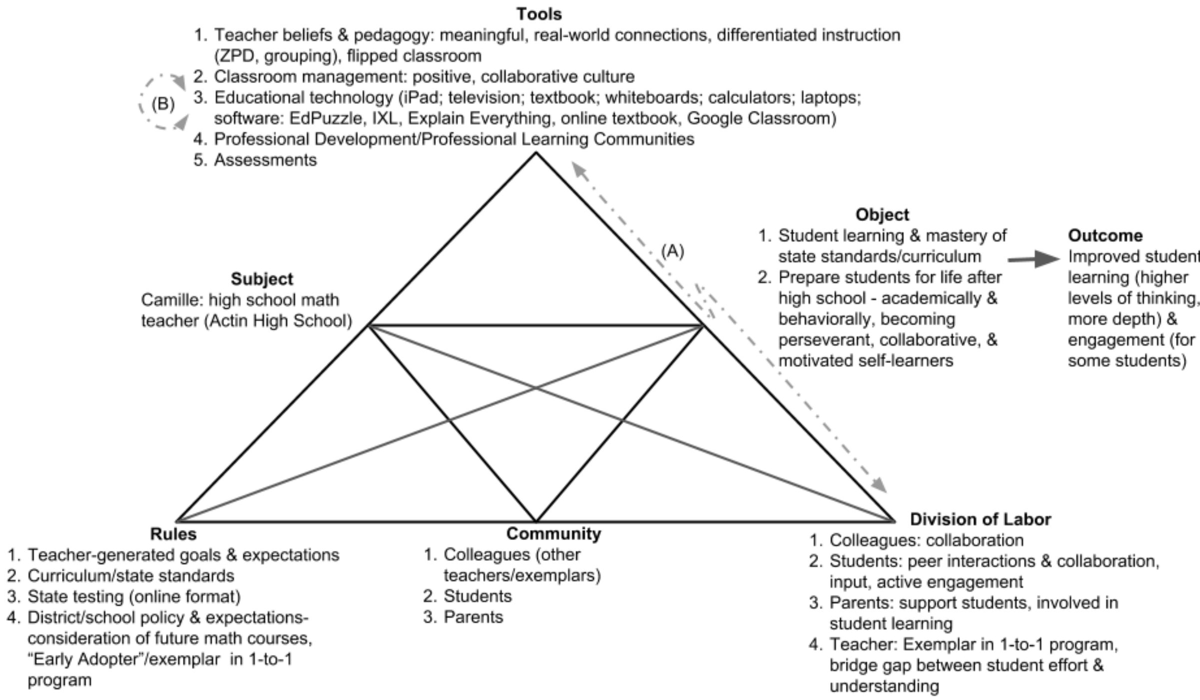

Figure 4. Triangle model of the activity system in Case 1. This figure illustrates the components of CHAT that were identified during Camille's engagement in the activity of teaching mathematics.

Tools. Camille employed numerous tools within this activity system. These tools included teacher beliefs and pedagogy, classroom management strategies, educational technology, and assessments. Various aspects of each of these tools are detailed below, as identified by the activity system analysis.

Teacher beliefs and pedagogy. Teacher beliefs and pedagogy were crucial tools in Camille's engagement in this activity, affecting the choices she made regarding the use of other tools, the application of rules, and the division of labor within the activity system. Camille emphasized the value of helping students build meaningful connections and discover real-world applications of the content. She explained that this helps retain student interest and helps students engage with the content on a deeper level. Camille stated:

> Sometimes if we get to modeling problems that we're talking about real-world examples and I find things that they're more interested in then we can kind of like delve into that [student interests]. I know I use a sports analogy for one of the things that I do, and one semester none of the students in my class played any sports whatsoever, and they didn't connect with that analogy at all. So we had to kind of take a step back, and I had to come up with another analogy that they connected with more. And if individual kids, you know, if they're really not connecting, and that's like I said, when I feel like I have thousand different ways to explain one concept, if they're not connecting with what we're doing, I try to kind of think about what are they interested in and what parts of the world do they have knowledge about. (1st interview, January 2018)

Camille also believed that all students in the classroom should be engaged in learning and always pushing themselves to improve. She wanted her students to "see the connection of why they're doing that process and why that makes sense," to develop understanding instead of simply memorizing (1st interview, January 2018). Camille's pedagogy and beliefs as a teacher were also reflected in the roles and responsibilities of the teacher, students, and parents (the division of labor), her employment of the flipped classroom model, and how various tools are utilized in her classroom, as described below.

Classroom management. During the two classroom observations (February & March 2018), the general classroom environment and classroom management strategies were observed. It appeared that Camille had created a positive, respectful learning environment in her classroom. Students were encouraged to collaborate with one another, as well as with Camille. She checked in with students often to determine how they were doing and what they felt they needed to be the most successful and maximize their learning in her class.

Differentiated instruction. Various aspects of differentiated instruction, such as the zone of proximal development, discussed previously in Chapter 2, were integrated in Camille's pedagogical practice. Camille expressed her belief that each student is unique. Camille stated:

> I feel like during undergrad and grad school and just teacher education, you know, you talked about differentiated instruction a lot. I feel like I got exposure to that even in my internship with a mentor teacher helping me learn the differences between how to kind of reach every kid and not just teach to the middle and see what sticks. And then of course PLC's [professional learning communities], I feel like that's something that you just talk about all the time, and it's always kind of on the forefront of your mind, which, even if you didn't want it to be, it has to be because your class is not made up of the same kid over and over and over again. You have kids all over the place (1st interview, January 2018).

She also explained that every child has a different comfort zone and that part of her job was to "figure out when kids hit that limit" regardless of students' ability levels; she wanted "all kids to hit that limit so that no matter where they are, [so that she] can push them to the next step" (1st interview, January 2018). This illustrates Camille's utilization of each student's zone of proximal development in an attempt to maximize learning for each student.

Grouping. Grouping was also utilized as a pedagogical tool in Camille's classroom. Students were typically seated in groups of two or three, and they were encouraged to discuss the problems together and think out loud. Camille stated:

> When they are thinking out loud together, they're processing more options that they maybe would be alone. And they tend to kind of think through more math that way than if they work by themselves, they're just trying to figure out the right answer instead of trying to figure out maybe why one method makes more sense than another. (2nd interview, March 2018)

This demonstrates Camille's focus on helping students develop problem-solving skills and collaboration in the classroom.

Flipped classroom model. Another one of the tools in Camille's activity system was the flipped classroom model, which involved both Camille's pedagogy and use of many forms of educational technology. In the flipped classroom model utilized in Camille's math classes, students watched video tutorials as homework in place of traditional pencil-and-paper activities. Camille created these videos using an iPad application called Explain Everything and assigned the videos to students to view at home using the EdPuzzle.com website. When students returned to class, Camille typically provided some brief direct instruction accompanied by practice with multiple examples as an entire class or with students in small groups, followed by individual student practice. Often this individual student practice took the form of online activities, using a program called IXL or the online textbook website. Students got immediate feedback during this online practice, which Camille explained was valuable in assessing student learning and in the planning and adjustment of student instruction. This also afforded Camille the opportunity to offer more individualized attention to students who were struggling the most, while allowing students who were excelling to move forward at their own pace. From Camille's perspective, these affordances of the integrated technology helped maximize student learning, as well as improved student engagement in the classroom. These benefits are discussed again in the "Outcomes" section below.

The flipped classroom model required students to adopt the role of an active participant in their own learning, contributing to the division of labor of this activity system. The division of labor is described more thoroughly in the next section "Community and division of labor." Camille stated, "with the flipped classroom, they don't really have as much of an option to be passive because they're given an hour's worth of work time and they're expected to work" (1st interview, January 2018). For the most part, Camille's students bought into this flipped classroom model and, based on classroom observations, students appeared to be actively engaged in the learning process and taking part in the routines of the class. According to Camille, students came into class already having an idea of what they would be learning that day, which helped build student confidence. Camille articulated:

> [The students] do buy into the fact that they kind of have an understanding when they come to class. It's not like they're coming to class and learning something brand new that day and then being very confused. They've at least seen it once before so it gives them, I think especially for those kids that don't have a ton of confidence, it gives them a little bit of edge. Like, what they're going to see on the board, it might still be confusing, but at least they've seen it before. It's not completely foreign. (2nd interview, March 2018).

The immediate feedback during online practice also built students' confidence by confirming that their work was correct.

The flipped classroom also allowed differentiation for students of varying ability levels, readiness, and learning preferences. Students could pause, rewind, and rewatch the video tutorials as many times as they need to. Camille explained that the video lessons in EdPuzzle allowed students to see Camille modeling the processes involved in example problems and explaining the content while giving students "a chance to go at their own pace" (2nd interview, March 2018). Additionally, if students were absent or missed instruction, they could keep current with the content so they did not fall behind the rest of the class. Camille required students to take notes on these videos; students had the option to take notes as they watch or to watch the video all the way through and return to take notes during a second viewing. The content of these videos was sometimes modified by student ability level. The videos Camille assigned to honors classes sometimes had a faster pace and greater depth than the videos she assigned to her lower level classes. Other times, a video tutorial was exactly the same for all levels of students, but Camille adjusted the depth and complexity of the practice exercises students complete during class the next day. Additionally, Camille included questions at the end of each video so students would "have a chance to know if they are on the right track or not" (1st interview, January 2018). To provide another mode of content presentation, at the beginning of the next class, Camille gave a short review of the concepts from the tutorial, and this appealed to some kids who perhaps had not grasped the content from watching the video.

Online practice. Online practice, which included both the online textbook skill practice and the IXL software program, provided Camille with opportunities to differentiate instruction. With regard to pacing, students who worked more quickly were permitted to do so, and students received additional time and individualized help as needed, either from the online resources or from Camille. Immediate feedback, which Camille named as "one of the biggest benefits…to the technology" in her classroom, allowed for differentiation by mastery and readiness (2nd interview, March 2018); students worked through problems of varying difficulty based on performance on previous problems and self-assessed their learning as they proceeded. Camille also integrated student choice in the online practice by providing students with a list of the skills, which sorted these skills from basic to more complex, and letting students work through the list in whatever order they chose to do so. Sometimes, alternatives to online practice were offered in the form of worksheets or pencil-and-paper practice.

Assessments. Frequent assessments, both formal and informal, were also found in Camille's repertoire of tools. Camille assessed student learning in a variety of ways. She observed students working during class, in groups and individually, and engaged them in conversation, which allowed her to gauge how well students were grasping the concepts being covered. Sometimes, informal formative assessment took the form of class games or competitions using the whiteboards. Student performance on the online practice activities also served as formative assessment, providing both Camille and the students with immediate individualized data about specific skills and content. Camille explained how the flipped classroom model and educational technology in the classroom allowed her to formatively assess student learning; she stated:

> We spend thirty minutes doing some kind of basic problems, and they spend a little bit of time practicing some deeper things, and so I think that helps me differentiate for all my students and gives me time when they come in everyday to assess where are they and how deep can we go…some lessons they get right away, and they are ready to dig into some deeper step, and sometimes we need to spend a lot of time or just really thinking about some more surface level problems. (1st interview, January 2018)

Students were also formally assessed at the end of each week when they took a test on paper over the lessons covered throughout the week. Camille used the data from both formative and summative assessments to reflect on her teaching and adjust future lessons as needed.

Community and division of labor. Camille did not act in isolation within this activity system. Based on interview and classroom observation data, the community consisted of colleagues, students, and students' parents. In the activity system's division of labor, the members of the community interact with one another, hold different positions, and share certain responsibilities during engagement in the activity (Engeström, 2001; Yamagata-Lynch & Haudenschild, 2009). Camille's pedagogical beliefs related directly to the division of labor within the classroom. Students' roles involved staying engaged in the learning process, working and asking questions. Camille described her role as the teacher as bridging the gap between students' effort and their understanding of the content; she believed that if students were putting forth effort and still not grasping a concept, her job was to provide students with as many alternatives or explanations as possible to help them reach a full understanding of the concept. Camille also stated, "if they're not doing their full effort, it's like I can't completely do my job because I need them to do it and show me everything they can do so I know how to help them pick up the slack" (1st interview, January 2018). This statement reflects Camille's intrinsic feelings of accountability for student success, as well as a certain amount of responsibility being placed on the student to actively contribute to their own learning.

Camille emphasized the importance of student input in her instructional decisions. She checked in with students often, asking them what they feel would be the most beneficial; for example, students were given the option to practice on the whiteboards, receive additional direct instruction, or work on online practice problems. Students were expected to be actively engaged and to provide honest input in the selection of classroom activities and in letting Camille know when they are ready to move forward or even deeper into a concept and when they need additional help or extra practice.

As another constituent of the community and division of labor, parents were also encouraged to participate in student learning. Camille explained that the video tutorials and online practice programs give parents a chance to get more involved and help their children learn and work through the math concepts.

> I've also found that [online practice and video tutorials] to be helpful because it is something [students] can do outside of the classroom, and parents have found that helpful too because parents can work with their kids and watch them do practice, and parents can also participate in helping their kids, which I think is something a lot of parents don't feel they have a chance to do in high school math, you know? They feel kind of out of the loop, but all of this for - since we have students that have online access - the videos and this online practice really do help parents to get back involved. And I think parents feel encouraged by that because even they can watch a video and try to learn a little bit of a skill and help their kid, or help their kid realize, "Yeah, we're both confused. You're going to have to ask the teacher." And that kind of gives the student confidence too to realize, "Okay, I'm not the only one that's confused, and it is okay to ask the teacher questions," which is something a lot of times freshmen struggle with. (2nd interview, March 2018)

As communicated in the statement above, even when both the parent and student could not grasp the concept, Camille believed the students felt more confident and empowered about coming in with questions for the teacher because they had seen their parent also struggle with that concept. This further contributed to the division of labor that was shared between the teacher, the students, and the parents.

In another aspect of the community and division of labor in this activity system, Camille collaborated with colleagues on how to best integrate technology in the classroom. Camille stated:

> We all come together and kind of share our experiences and learn from one another; I think those are really helpful discussion points because as a single person the technology world is really big. There's only so many things you can come across and so many way that you can be creative in your own mind. So learning from other people's experiences, how they use it, how you could maybe adapt that or explore those opportunities, is I think probably the most helpful thing…just learning from each other. (3rd interview, May 2018)

The teachers at Actin High school, especially the one-to-one initiative exemplars, shared the responsibilities of seeking out and trying new technology-related strategies in their classrooms. They then communicated with one another about their experiences with using the various forms of educational technologies in their own classrooms so others could determine if that technology was something they wanted to try to incorporate in their own teaching practice.

Rules. The rules of the activity system influenced Camille's instructional decisions on the use of educational technology. State standards determined the concepts and depth of content covered in Camille's class. Additionally, the format of the state's end of course exam affected various aspects of Camille's instructional choices, including how she teaches certain concepts, how students practice these concepts, and how students assess their own understanding. In preparation for the state's end of course exam, which is administered on an online platform, Camille provided students with various online activities, allowing them to get immediate feedback and also to practice with using an online interface. Camille explained, "for math, entering an equation and graphing an equation on an online platform can be very different that just doing that pencil to paper" (1st interview, January 2018). The online format of the state-mandated end of course exam influenced Camille's instructional decisions to provide students with these opportunities to practice with digital tools in the classroom. As a result, the students built both content knowledge and confidence in taking the online end of course exam.

Camille also described certain responsibilities to use educational technology as an Exemplar in the one-to-one initiative at Actin City Schools, adding another layer to the rules guiding Camille's use of educational technology in the classroom. She stated:

> For our district and my school, I have a set of classroom computers in my classroom, so as one of the first people in that initiative to have that classroom set, I definitely feel – not pressure – but…that's a resource I've been afforded so I need to make sure that I use that when it's appropriate (2nd interview, March 2018).

Camille went on to explain that she only used technology when it made sense and added value and efficiency to an activity or lesson. The classroom set of Chromebooks increased the accessibility of online resources compared to Camille's past experiences, when she had to reserve a computer lab, walk the students down to the computer lab, and get them settled into that location and logged onto those computers. Camille's access to these technological tools and her sophisticated pedagogical knowledge helped her to enact her commitment to equity and maximizing learning opportunities for every student in her classroom.

Outcomes. As a result of the interactions between the factors in Camille's activity system, the outcomes included improved student learning and engagement. Camille credited the flipped classroom model with allowing her "more time in class to actually give instruction and see how students are doing and to kind of dive deeper…work[ing] on higher levels of thinking and not just skill and drill" (2nd interview, March 2018). This additional time helped her students make deeper connections with the content and also allowed them to understand the "why" and not just the "how" of doing math (2nd interview, March 2018). According to Camille, students have become more actively engaged in their learning since she implemented the flipped classroom model and integrated more technology in her classroom. She stated:

> I do use technology here and there for the practice; it keeps kids engaged when they're using it, just because it's mixing it up. It's kind of the same if you were to assign kids problems out of an old text book that they had to copy on notebook paper versus giving them a worksheet versus giving them an activity to do. It's just kind of a different, a different medium, so it keeps them engaged, which is of course a better use of class time instead of listening to them moan and groan and whine about having to do anything. (2nd interview, March 2018)

The students' actions during classroom observations also served as evidence of this engagement; students remained on task, participated in on-topic conversations as they collaborated with their peers to solve problems, and provided Camille with feedback about their progress and understanding of the material.

Analysis of Contradictions within Camille's Activity System

Contradictions and tensions were also identified within Camille's activity system. The contradictions can be classified as one of four types, or levels, as previously described in Chapter 3. Occasionally, some students did not "buy into" Camille's flipped classroom, failing to watch the assigned video tutorials or complete some of the assigned work; however, Camille stated that these are "kids who probably would not be doing anything outside of school anyway" (2nd interview, March 2018). This is a secondary contradiction because there was conflict between two constituent components of the activity system: division of labor and tools, as shown in

Figure 4 as contradiction A. These students did not want to perform the tasks required to actively engage in the instructional activities involved in the flipped classroom model, which was one of the pedagogical tools in this activity.

Other students did not like the process and format involved in using Chromebooks to complete math assignments. Camille stated, "typing math is weird, and some of the programs we've used before are not very user-friendly so they don't love that. They get frustrated about that, but I've only had a very few feel that way" (2^{nd} interview, March 2018). Some of the activities and functions of the online textbook were not particularly useful or user-friendly for students. According to Camille, the graphing utility of the online textbook software did not help students learn the imperative skills so she chose to have students practice on whiteboards and worksheets instead of using the textbook's online practice exercises for certain concepts. The questionable utility of some of the new technology-based strategies, as well as the flipped classroom model itself, presented tertiary contradictions. Both the use of new technologies and the flipped classroom model can be viewed as more advanced forms of the original central activity of classroom instruction, and, in this case, both were met with resistance from some of the students.

Accessibility of technology outside of school was found to be another tension created by conflict between the more advanced form of technology-assisted instruction and the more traditional forms of instruction that rely to a greater extent on in-class lectures, textbooks, and paper-and-pencil assignments. While most of Camille's students had access to technology outside of school, some of her students did not, which created a barrier or obstacle for those students in accessing the video tutorials and online resources. Camille explained that Actin High School did, however, have mandatory tutoring time each morning that provided students with an opportunity to use the technology available in the classrooms before school began each day, allowing them to view the content and prepare for class.

The Chromebooks also served as a distraction for some students. Camille observed some students using the Chromebooks to work on assignments for other classes or to view websites besides those she has assigned or approved. The double nature of this tool can be viewed as a primary contradiction (contradiction B in Figure 4) where the educational technology provided access to resources and learning opportunities and also served as a distraction or form of nonacademic entertainment for students who chose to misuse the Chromebooks. As a result of the tension created by this contradiction, Camille developed strategies to discourage students from misusing the technology. She explained that she combatted off-task Chromebook usage by limiting the time students spend on the Chromebooks and personally circulating around the classroom and monitoring as students work. Camille also explained that she gave her students a set of assignments and a set amount of time to work on these assignments so "they don't have much time to roam" (2nd interview, March 2018). According to Camille, if she noticed a student misusing the Chromebooks, she took away their technology privileges for the day. She said the students then realized how much easier it would have been to be able to use the technology, and they worked to regain their technology privileges.

Case 1 Summary: Coherences and Contractions

To summarize this case, Camille, a math teacher at Actin High School, was observed and interviewed about her teaching practices in a STEM-related high school, with a focus on the practices related to the use of educational technology for the purposes of differentiated instruction. Through the use of activity system analysis, the subject was identified as Camille, and her objects, or goals and motivations, were identified as student learning and mastery of state standards as well as working toward student preparedness for life after high school, both academically and behaviorally. Camille utilized numerous tools in pursuit of these objects, such as formal and informal assessments, several forms of educational technology, and teacher beliefs and pedagogy.

Rules were also identified within this activity system. For example, the state standards, online format of the state-mandated end of course exam, teacher-generated goals and expectations, and district/school expectations all influenced or guided Camille's instructional decisions and engagement in the activity of teaching in various ways. The community of individuals that interact with the subject included colleagues, students, and parents. The division of labor, which involves the responsibilities and positions created for the participants in the activity, was also intertwined with the other components of the activity system. Colleagues shared collaborative duties. Students were expected to interact and collaborate with their peers and to provide Camille with input about their progress and understanding. Parents' duties included supporting students and being involved in their child's learning. Camille's role as a teacher included acting as an exemplar in the Actin City School district's one-to-one technology initiative; in the classroom, Camille took on the responsibility of bridging the gap between student effort and understanding.

Multiple contradictions existed within this activity system as well. For instance, some students did not buy into the flipped classroom model and failed to perform their expected tasks and duties. In another contradiction, the Chromebooks possessed a dual nature in Camille's classroom; sometimes the Chromebooks were utilized as academic tools, as Camille intended, and sometimes they became a distraction when students used them for entertainment and nonacademic purposes. Camille responded to the tensions created by these contradictions. If students misused the Chromebooks, students the faced consequences of having to do their work without the use of this technology until they were able to earn that privilege back. If students did not complete required tasks and duties, their grades and learning potentially suffered; Camille tried to foster a positive learning environment with peer collaboration to encourage student participation and buy-in.

Within this case, educational technology was employed to differentiate instruction on multiple occasions. Additionally, during interviews, Camille discussed how she used education technology to address multiple components of differentiated instruction to meet the needs of diverse learners in the classroom. These topics are highlighted again at the end of this chapter in the cross-case analysis in the analysis of this study's research questions.

Case 2: Jemma

Professional Background and Present Experience

Jemma is a math teacher at Actin High School. Her highest level of education is a Masters degree in Biomedical Engineering, and she has fifteen years of high school teaching experience. She has taught several subjects, including Geometry, Algebra I, Algebra II, Precalculus, Ecology, and ACT Test Prep. The school year during which this research was conducted (2017-2018) was Jemma's first year using a classroom set of Chromebooks in her classroom.

Jemma's interest in STEM began when she was a child. She recalled taking devices, such as typewriters, apart to investigate how they worked and then putting them back together. She also related her interest in STEM education to early experiences with problem-solving, when she discovered an error in the coding in a computer programming magazine and was able to correct the mistake. Jemma carried her enthusiasm for problem-solving and engineering into the math classroom. Jemma struggled as a student herself, claiming that she had learning disabilities and would have most likely been considered dyslexic, although she was never formally diagnosed. She explained that she identified with students who struggle and worked with them to overcome their own obstacles and accomplish their own academic goals.

Activity Systems Analysis: Jemma

Subject and object. A graphic summary of the Case 2 activity system, as analyzed using the CHAT framework, is shown in Figure 5 below. Jemma was the subject of the activity system in this case. Jemma's goals and motives, which make up the object of this activity system, included helping students learn and master the state standards and helping students build motivation and perseverance in learning. When asked what she believed good teaching looks like in her classroom, Jemma responded: "The kids buy into it, and, no matter how hard it gets, they just won't give up. They can ask me a million questions, and I'll answer a million questions, but just that they continue to ask" (1st interview, January 2018). The object of an activity influences, and is influenced by, the other CHAT components: the tools, community, division of labor, and rules. These CHAT components in this case are discussed below.

Tools. Jemma utilized many tools during her engagement in the activity of teaching a STEM-related course. These tools included Jemma's pedagogy and beliefs as a teacher, which were connected to the use of the flipped classroom model, student grouping, and differentiated instruction. Other tools included classroom management, several forms of educational technology, and assessments. The following sections detail each of these tools.

Flipped classroom, differentiated instruction, and educational technology. One of the tools employed by Jemma was the flipped classroom model. In this model, students were expected to watch the lectures as videos for homework. These videos were created by Jemma

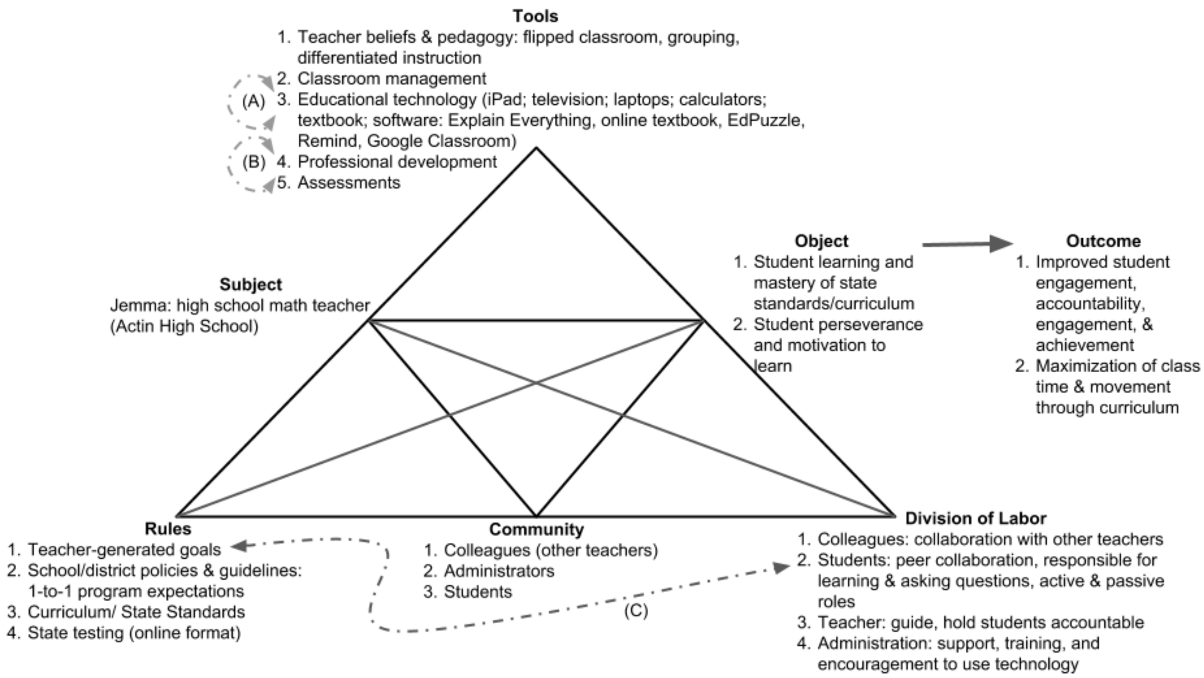

Figure 5. Triangle model of the activity system in Case 2. This figure illustrates the components of CHAT that were identified during Jemma's engagement in the activity of teaching mathematics.

using the Explain Everything iPad application and assigned to the students through EdPuzzle.com, which linked to students' Google Classroom accounts. Students then worked problems together and on their own during class. Jemma how the flipped classroom model worked in her classroom, saying:

> The students have to kind of learn the routine, but I'm really trying to get them to, even when maybe somebody else is working some problems that we're working on, if they've got it, then they can go ahead and start their online work – their individual work. Then the individual work gives them instand feedback if they're getting it or not, versus me just being able tot get around to twenty something kids in the classroom individually because

> they all do things differently, but because I also want them, especially with that level, to point out where they made their mistakes. (1st interview, January 2018)

With this flipped classroom model, Jemma incorporated numerous forms of software into her class routine, including EdPuzzle, Google Classroom, and the online textbook. The educational software and flipped classroom model allowed students to somewhat work at their own pace. This was aided by the instant individual feedback provided by the online textbook practice software, which also afforded Jemma more time to work one-on-one with students who needed help the most. With this software, Jemma could control the number of attempts students had for each problem, as well as differentiate by student readiness and ability level by adjusting the percent mastery each student must reach.

With the classroom set of Chromebooks, students also had access to a wide variety of online resources that could help them work through challenging material. Jemma encouraged students to use these resources during their independent practice time because "maybe something will be said in a way that they'll understand it better" (2nd interview, March 2018). The online practice also provided students the opportunity to complete more problems than Jemma required if they desired extra practice or wanted to go even further into a concept. This was another example of how the technology integrated into Jemma's class allowed for differentiated instruction. While technology could sometimes be viewed as a distraction (discussed further in the analysis of contradictions within this activity system below), if students were venturing onto other noneducational websites or using the technology in ways that the teacher did not intend for them to, Jemma made the argument that flipping the classroom could actually take away some of the normal distractions of the classroom. Jemma stated that she could ask students questions and "get individual feedback without a million other distractors, and then they come in and, based upon where they're at, some students get to continue on and other students [need] more individualized instruction to get them to a good foundational understanding" (1st interview, January 2018). Students could watch the videos without other students in the classroom who may have distracted them from what the teacher was saying, and students could communicate their own questions individually to the teacher, using email or the Remind program, or formulate their questions and bring them to morning tutoring or to class.

Assessments. Jemma administered formal assessments, another tool, on paper. Jemma explained that with some online assessments, if students were told immediately that their answer is correct or incorrect, some students became anxious or even gave up and just started clicking random answers. She stated, "Those times they tell you if you are getting them right or wrong, they just start clicking and freak out" (1st interview, January 2018). Paper tests allowed Jemma to give them partial credit, whereas the online assessment tools that Jemma had tried do not. Potential cheating was another reason why Jemma chose paper tests over digital assessments, as mentioned above. Jemma did not have a way to monitor all students' screens at the same time, presenting the risk that students may visit other unapproved websites during an online assessment to try to find the correct answer instead of working through problems on their own.

Grouping. Strategic grouping was also employed in Jemma's classroom activities. Jemma addressed the importance of getting to know her students in making grouping decisions in the classroom. While social components were taken into consideration, Jemma tried to group based on ability. She tried to place higher achieving students with lower achieving students in heterogeneous grouping. Sometimes, however, she noticed that two students may have approximately the same ability levels but happen to engage more with the material when they work together. According to Jemma, "I change my groups all the time, so it's constantly changing based upon what I observe going on in the classroom" (3rd interview, May 2018). This flexible and adaptive grouping was another component of differentiated instruction that was identified as a part of Jemma's pedagogical practice.

Community and division of labor. The community in Jemma's case included Jemma's colleagues, school and district administrators, and the students. The members of this community held different positions and responsibilities during the engagement of the activity. As part of this division of labor, Jemma collaborated with other teachers on best teaching practices, including those that integrated educational technology. According to Jemma, this collaboration with her colleagues helped create a "shorter learning curve" in using new technologies and strategies in the classroom (2nd interview, March 2018). These teachers essentially tried out the technologies and strategies and shared with one another what worked well for them and what did not.

Jemma believed her role in the classroom was to act as a guide, and she encouraged her students to take responsibility for their own learning. Jemma also explained that she holds students accountable for getting help when they need it, stating, "When they get stuck, it's their responsibility to ask" (1st interview, January 2018). According to Jemma's class policy, students were allowed to retake tests, but they had to take initiative and work with Jemma to make that happen. The role of the student could be classified as both passive and active, depending on the activity. Students were expected to watch the video tutorials, and Jemma verified which students had watched each video using EdPuzzle.com. This program also allowed Jemma to see if students rewatched certain portions of the video multiple times, gaining insight into topics or concepts students may have found more confusing or challenging. During the videos, students were watching and listening, which Jemma considered passive, but they were also taking notes on the video tutorials and working practice problems along with the video, which could be considered more active. During class time practice, students took on a more active role as they worked through various exercises together and individually, sometimes on paper and sometimes online. Jemma also used an online texting program called Remind to communicate with students. Students could use this same program to contact Jemma if they were having trouble with some of the technology, like if a video tutorial was not working. This, again, allowed students to actively participate and take ownership of their learning.

The Actin High School administration encouraged the use of educational technology. More specifically, the administration asked teachers to make use of the Chromebooks to access certain forms of software, including Google Classroom. Administrators provided training and support for teachers and allotted specific time for the one-to-one initiative exemplars to meet and collaborate on how to best utilize this technology in their own classrooms.

Rules. As mentioned above, there were expectations at the school and district level related to the one-to-one technology initiative and how the exemplars, the first teachers at Actin City School to have classroom sets of Chromebooks, were supposed to use the technology. These expectations were among the rules that guided Jemma's engagement in the activity of teaching, which included the use of educational technology to differentiate instruction in her classroom. Jemma commented on the integration of technology in the classroom, saying "We're all going to computer-based, one-to-one, so because of that then there's a lot more computer-involved" (1st interview, January 2018).

Jemma also referred to the state standards and state assessments as influencing her instructional decisions. The state-mandated end of course exam was delivered using an online platform, which further affected Jemma's choices to utilize online practice in her daily class routine. She stated, "Our state testing is all on computer, so I want them experienced with testing on computer" (1st interview, January 2018). Even though the testing and practice platforms were not identical, Jemma explained that the online practice helped students build patience and understanding of how submitting responses online differed from pencil-and-paper exams.

Outcomes. Jemma identified several different results, or outcomes, from the integration of one-to-one technology in her classes. According to Jemma, the flipped classroom model and online practice activities improved student motivation and accountability. Jemma explained that when students work on the online practice activities, "most of them actually go to 100 [percent mastery]. They want 100…and then I have control over how many attempts they get" (1st interview, January 2018). Additionally, since the integration of the Chromebooks in her class, Jemma claimed she had seen improvements in student engagement and achievement. Jemma believed the flipped classroom model and online practice resources allowed her to maximize class time and move even more quickly through the curriculum.

Analysis of Contradictions within Jemma's Activity System

Jemma's students used internet-based programs, such as the online textbook, to practice and complete daily assignments. For testing purposes, however, Jemma preferred to give weekly assessments on paper because she did not have a way to lock down the students' web browsers to prevent them from visiting other sites during testing. This contradiction, shown graphically on Figure 5 as contradiction A, was classified as a primary contradiction, with the educational technology having double nature as a tool for learning as well as a tool that could facilitate academic dishonesty. To deal with the tension caused by this contradiction, Jemma chose to use paper-and-pencil tests instead of using digital means to formally assess student learning.

The Chromebooks were also sometimes used inappropriately by the students during daily practice and activities. This additional aspect of the educational technology's dual nature is also shown as contradiction A on Figure 5. The Chromebooks, an educational technology tool, served as an academic resource in some instances and as a distractor and facilitator of academic dishonesty in other instances. Some students used the Chromebooks to access nonacademic websites that Jemma did not intend for them to use. Some students attempted to cheat by using other websites to get through the assignments more quickly, with no regard for actually learning the concepts and material. Jemma described this contradiction, saying:

> They can always get distracted by something else on the computer, and that's a big issue. I know other schools have where kids come in the room, it links up with their teacher's device, and the teacher can block things individually in the class. We don't have that. I wish we did. We need that because kids are pretty slick. (2nd interview, March 2018).

As a result of the tension caused by this contradiction, Jemma circulated throughout the room often, visually observing whether or not students were using the Chromebooks appropriately. If Jemma found students breaking the rules related to technology in the classroom, students were at risk of losing their technology privileges.

Another primary contradiction, contradiction B in Figure 5, was identified within the tool of professional development. Jemma specified:

> I went to a professional development this year, and they had different groups about differentiating instruction or technology, and you go to one and they tell you one thing, and you go to another one and they contradict each other. That's really frustrating when you're really trying to find stuff that works. (3rd interview, May 2018)

The conflicting information presented at this professional development caused negative feelings of confusion and frustration for Jemma, increasing the difficulty of making instructional decisions related to her pedagogical practices of differentiated instruction and educational technology integration.

During the first and second interviews, Jemma explained that some students did not take initiative in their learning. These students did not take advantage of the opportunities to contact Jemma about problems they were having, either with using educational technology, such as accessing videos on EdPuzzle.com, or with understanding the content itself. Jemma also stated, "Some of the kids don't want to ever listen to the video; they just want to watch it, and so that's a challenge. There's no way to force them to listen" (2nd interview, March 2018). This illustrates a secondary contradiction between the rules and division of labor components of the activity system, shown on Figure 5 as contradiction C. More specifically, these students' failure to take responsibility for their own learning conflicted with Jemma's expectations for student engagement and initiative in the classroom.

Case 2 Summary: Coherences and Contractions

In Jemma's case, Jemma engaged in the activity of teaching mathematics with the goals of student learning and mastery of the state curriculum in mind. Jemma also wanted to improve students' perseverance and motivation to learn. Jemma employed numerous tools in her pursuit of this activity. Among these tools were professional development, teacher beliefs, and pedagogy, all of which influenced the incorporation of the flipped classroom model, grouping, assessments, and differentiated instruction into Jemma's teaching practices. Additionally, many forms of educational technology were employed as a part of the flipped classroom and as the school system was implementing a one-to-one technology initiative.

Jemma's community consisted of her colleagues, administrators, and students. Jemma's colleagues shared a collaborative role within this activity system, while Jemma acted as the guide who held students accountable within her own classroom. Students were expected to collaborate with their peers and assume both active and passive roles, taking responsibility for their own learning and asking questions when needed. Jemma's administration provided support, training, and encouragement, especially with respect to the integration of educational technology in the classroom.

The pursuit of the activity in this case was guided by various rules, such as teacher-generated goals and expectations, policies and expectations at the school and district level, and the state mathematics curriculum and mandated testing. The outcomes of this activity system included improved student engagement, accountability, motivation, and achievement, as well as maximization of class time and enhanced pacing through the curriculum.

Contradictions were also identified in Jemma's case. Jemma's students sometimes misused the educational technology, as a result of the dual nature of this tool. In another primary contradiction, Jemma felt that the professional development sessions sometimes presented conflicting information, preventing this tool from assisting in the attainment of the activity system object. Some students failed to take initiative or responsibility as part of the division of labor in this activity system, again preventing the attainment of Jemma's goals. The findings of this activity system analysis are analyzed in the context of the research questions and compared to those of the other cases in the cross-case analysis at the end of this chapter.

Case 3: Simon

Professional Background and Present Experience

Simon is a math teacher at Actin High School. In college, Simon was initially interested in engineering, but, after realizing he was interested in the mathematical component of engineering and not the business component, he changed his major to mathematics. His focus on relationships and social interactions led him to education, and he eventually earned an Education Specialist degree in Administration. Simon has twenty-two years of teaching experience; he has taught 8th grade Math, Algebra I, Algebra II, Geometry, Calculus, Precalculus, Physics, Physical Education, ACT Test Prep, and a Career and Technical Education (CTE) course titled Innovations and Inventions. During the time of this research (2017-2018), Simon taught 9th grade Algebra I.

Activity Systems Analysis: Simon

Subject and Object. Figure 6 (below) summarizes the activity system of this case as analyzed using CHAT. The subject in this activity system was Simon, and the activity was teaching mathematics, a STEM-related course. With regard to the object of the activity, Simon aimed to motivate students and improve student learning and engagement. He also wanted to help students develop an enjoyment of math and view mathematics from different perspectives, especially with the integration of technology. Simon also strived to prepare his students for success in future math courses.

Tools. Simon employed several tools in pursuit of these objects. These tools included teacher beliefs, pedagogy, educational technology, and assessments. Simon's utilization of these tools in this activity system is discussed in greater detail below.

Teacher beliefs and pedagogy. As part of Simon's pedagogical practice, Simon implemented the flipped classroom model. Students watched video tutorials for homework to introduce the material, and, when Simon provided direct instruction during class, the material was explored in greater depth and complexity. Class time was used to practice skills and develop greater understanding of the content. Simon claimed that flipping the classroom made him "dig deeper into the topics" and hoped that this improved his teaching (3rd interview, May 2018).

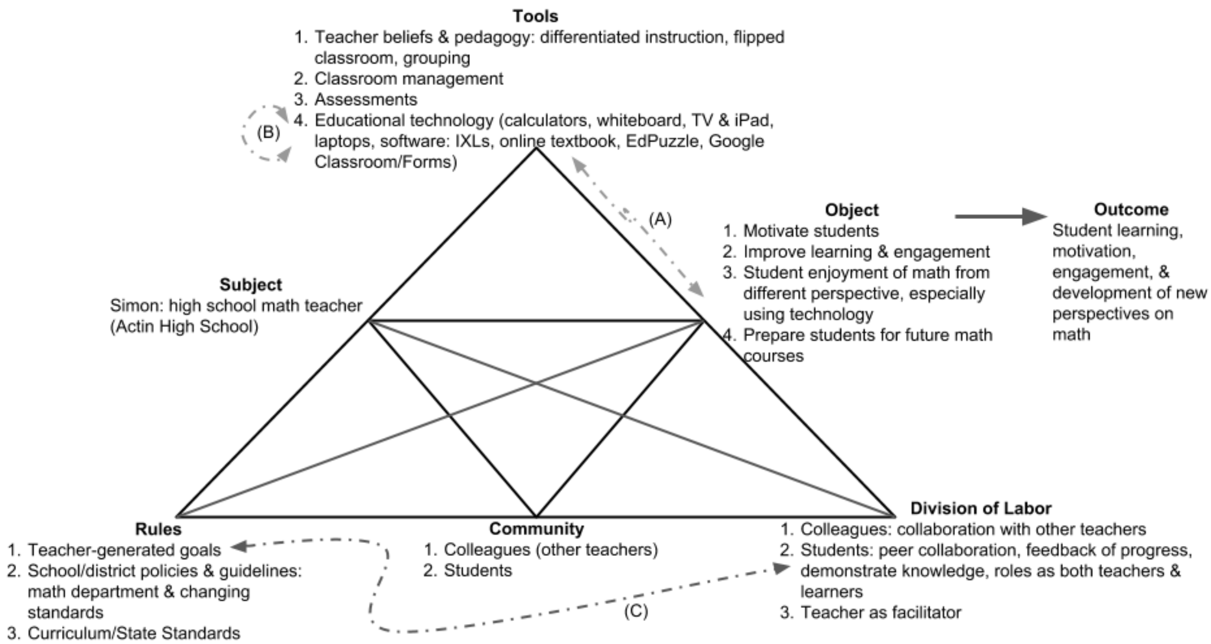

Figure 6. Triangle model of the activity system in Case 3. This figure illustrates the components of CHAT that were identified during Simon's engagement in the activity of teaching mathematics.

Simon incorporated differentiated instruction into his teaching practice as well, sometimes placing students into groups to work collaboratively and other times having students work independently; Simon believed "if they are working together, even if they struggle through it, they're at least being engaged instead of me just spitting out a bunch of facts or rules…it's the peer interaction that really engages learning" (1st interview, January 2018).

When asked about his beliefs pertaining to differentiated instruction during the first interview, Simon responded:

> It's what every teacher should do every day anyways. It's offering multiple ways for students to learn and engage in learning. In terms of my class, I always tell the students

> they have anywhere from four to five opportunities to learn the material. They can learn it by purely watching a video, and they might attain most everything they need to through the video. It may be more of a direct instruction component, where I'm standing in front of them and they can ask questions or something of that nature; so that have that opportunity. It may be purely through practice, which on the online homework is pretty good because it give them examples. It can take them step by step, and, if they miss a problem, they can always go back to try another one and try to rework it…Differentiating instruction for me, means making every opportunity available for every student to be successful in your class. (1st interview, January 2018)

This statement illustrates Simon's understanding that students have different learning styles and different needs, which lies at the heart of differentiating instruction for diverse learners. In another component of differentiated instruction, Simon also used formal and informal assessments, discussed in greater detail below, to measure students' progress and mastery of the content, adjusting the instruction and pacing as needed.

Educational technology. The classroom set of Chromebooks, another tool, facilitated Simon's use of the flipped classroom model and differentiated instruction by allowing students to complete online practice and control their own pacing to some extent, proceeding more slowly if needed or moving ahead when they have mastered certain concepts. Simon also stated that the integrated technology in the classroom allowed him to better match the practice to students' ability levels, giving students who have mastered basic concepts the opportunity to look more in-depth at problems requiring higher levels of thinking. By utilizing various online tools, such as video tutorials on EdPuzzle.com and the IXL online practice, Simon was able to more efficiently meet the needs of the diverse learners in his classroom, as opposed to when he previously had to create paper copies of different assignments and different assessments to try to accomplish this goal. In Simon's opinion, because of the integration of educational technology in the classroom:

> The students have more opportunities to be successful…since they do a lot of the online stuff, and they can do multiple retries and see examples and that sort of thing. I think it helps meet the instructional needs for every student across the board more so than I could have with pencil and paper homework. The online [practice] has really given those students that struggle a better opportunity to grasp concepts and work through it more frequently. (3rd interview, May 2018)

Simon also believed that integrating educational technology could be a way to get students' attention and pique their interest in the subject matter to a greater degree than traditional paper-and-pencil work. Simon stated:

> I think [technology]'s a catch for them, or a hook…they always talked about having a hook to get students caught in, and I think technology now is kind of that hook for all students because if they can use their phones or use a Chromebook or iPad or whatever, I think for some students, it engages more so than if you just put a piece of paper in front of them. Now, that's not for all students, but I do think that as a whole it's become kind of that hook to get students engaged. (2nd interview, April 2018)

With this statement, Simon emphasized the importance of appealing to students' interests as a way to get them involved in their learning, which can be viewed as a component of differentiated instruction.

Assessments. Assessment is an important instrument for gauging students' level of interest, learning, and engagement. Simon relied on student feedback, student questions, and student answers to indicate who has grasped certain concepts and who is still struggling. Simon also utilized the available technological tools, such as IXL practice assignments and online textbook practice exercises, to determine which questions students were missing or struggling with, allowing him to identify content and concepts that needed to be retaught or refined. Simon explained that educational technology had also changed formative assessments and practice in his classroom; when creating online assignments, Simon specified the importance of:

> Looking specifically at the questions, what they ask, what's required of it; looking at: Is it a good question? Does it meet the standards? Does it not meet the standards? Does it relate to our course test? And if so, how does it relate? I feel like all those things have made me dig a little bit deeper into the content. (3rd interview, May 2018)

The online practice provided students with immediate feedback that helped the students gauge their learning and move on to more challenging concepts or the next lesson in the curriculum if they were ready. These online assignments were "timed and very quick, and so with those I can see very quickly how much of the basic concepts students have acquired…just by doing those" (3rd interview, May 2018). This allowed both the students and Simon to assess students' understanding and mastery of the content and provided opportunities to differentiate instruction to cater to the diverse needs of students in a responsive way.

Simon began and ended each course with a diagnostic test. This tool provided Simon with insight into the strengths and weaknesses of each student and each class as a whole. Simon used data from the pre-test to determine if he needed to spend more time going over some prerequisite skills early on or if they could move more quickly into new content. Simon specified:

> Every class that comes in is different, so I always have a diagnostic test that I do at the beginning and at the end of the course, and that gives me some insight into foundationally

> where classes are and maybe concepts I may have to spend a little bit more time, prerequisite concepts early on, just to make sure that kids are not left behind because I certainly don't want to start something, and they have no knowledge and then never get it. (1st interview, January 2018)

This statement demonstrates certain aspects of Simon's use of assessment to aid in differentiation, with Simon acknowledging the uniqueness of each class and the importance of adapting instruction to fit the needs of his students. Formal assessments, or tests, that occurred throughout the course helped Simon modify instruction to ensure that students were building solid understanding of the material, as well as to make decisions about which concepts to emphasize during review in preparation for the end of course exam.

Community and division of labor. Based on classroom observations and Simon's responses during the interview sessions, the students and collaborating teachers made up the community of this activity system. The division of labor, or shared responsibilities among participating members of the community, included Simon as the facilitator of the classroom; he explained that he had learned to let go of some of the control of the classroom and to encourage peer interaction. Approximately fifteen minutes of each class was spent with Simon providing direct instruction, clarifying and modeling concepts, techniques, and examples to the students. The majority of the remaining time Simon facilitated student learning by helping individual students one-on-one and monitoring group work. He believed if students were working together, even if they are struggling, they were more engaged in learning than if he were to solely rely on direct instruction or lecture. When asked to describe students' role in the classroom, Simon responded:

> They should have already seen any videos since I flip my classroom…so when I do the direct instruction it's basically delving a little bit deeper into the specifics of the content, as well as implementation of the technology…and then after that, then the students become not just students but hopefully engaged teachers as they work with their peers through things, and they're bouncing ideas off of each other and teaching one another and working with each other. They're becoming teachers and learners at the same time, and that's typically, or ideally, what I would feel like the class looks like and how the student's role evolves during the class time. (1st interview, January 2018).

Simon explained that, depending on the makeup and chemistry of the class, he had to find a balance between letting students work in groups, letting students work individually, and providing students with an appropriate amount of direct instruction. This provided differentiation by giving the students multiple ways to access and work with the content, meeting the needs of students who learn in different ways.

Students also participated in decision-making on certain aspects of the class. For example, Simon offers opportunities to complete an assessment with a partner. Simon explained:

> One of the things I do is a partner quiz and a partner test. They have one per semester, and they as a class decide when to utilize that. They also pick their partner so that's them being engaged in terms of when they find concepts to be difficult, and there's an assessment coming, and they feel like they would do better to work with someone or together. In some cases, it might be a group of three, they have that opportunity or choice as a class and can do that. (1st interview, January 2018)

Students were also allowed to choose from different forms of online practice, sometimes having the option of completing additional problems for extra credit. Although students' roles evolved throughout the class period, students were expected to be actively engaged in the learning process the majority of the time.

Simon described the importance of collaboration with colleagues, especially with the integration of technology and the application of the flipped classroom model. One of Simon's colleagues has greatly influenced changes in the pedagogical choices of the other math teachers at Actin High School. When speaking about this division of labor and the roles of collaborating teachers, Simon stated:

> I think once certain other math teachers started with the flipped classroom, it kind of engaged all of us to start looking at different ways of teaching. He kind of branched out. He did the Power Teaching. He's really kind of moved ahead as times have changed and tried to think about different ways, and I think that prompted at least myself to look at that and how to do that…And then we have ideas and can share and figure out maybe how to integrate [technology] within our classroom. (2nd interview, April 2018)

Simon explained that collaborating with other teachers in his department allowed them to share ideas and technological resources, even though the teachers may choose to use those technologies and strategies in different ways in their own classrooms. This collaboration with colleagues exposed Simon to new technologies and allowed him to use these technologies to better differentiate instruction in his own classroom.

Rules. The rules of each activity system guide and regulate the subject's engagement in the activity. One set of rules identified in this activity system included the curriculum, or state standards, that students were tested on at the end of the course. Simon stated:

> I'm not going to live and die by that state test. As long as I've covered the concepts that I know [students] have to have to be successful for the next advanced math class, then that is my goal, to make sure we get that in. (1st interview, January 2018)

Simon worked to cover as much of the material that students see on the state-mandated end of course exam as time will allow; however, Simon explained that this set of state standards was not his "direct guideline," and that these standards determined what he taught but not how he taught it.

Simon also described the importance of collaboration with his colleagues and how this collaboration guided his instructional decisions. At Actin High School, the math teachers decided as a department how to handle changes in standards when certain skills were moved from one course into another, serving as rules or guidelines that existed at the school level. While Simon did not mention any officially mandated school or district policies on the use of technology, he did explain that collaboration with the other Actin High School math teachers influenced his own use of technology in the classroom. Simon specifically mentioned the influence of colleagues' use of the flipped classroom model, stating:

> I think once certain other math teachers started with the flipped classroom, it kind of engaged all of us to start looking at different ways of teaching. He kind of branched out; he did the power teaching, he's really kind of moved ahead as times have changed and tried to think about different ways, and I think that prompted at least myself to look at that and how to do that. I definitely think technology has allowed us as a department to communicate and to share ideas to collaborate a whole lot more because we all use it, sometimes in different ways. Then we have ideas and can share and figure out maybe

> how to integrate that within our classroom. So I think it's really prompted a lot more collaboration amongst our department anyway. (2nd interview, April 2018)

Because Simon saw potential benefits of this model for his own students, such as individualized pacing and greater accessibility to content, Simon integrated the flipped classroom model into his own teaching practice. As mentioned above, the teachers in this department shared ideas about how to use technology and other tools in their classrooms, and each teacher decided what worked best for their own classes and students. These rules contributed to the use of educational technology to differentiate instruction as Simon worked with his colleagues to determine which technologies and strategies helped meet the needs of all students in their classrooms.

Outcomes. Outcomes in Simon's activity system included improvements in student learning, motivation, and engagement. During the classroom observations, students actively participated in various instructional activities, including following along with Simon's direct instruction and engaging in online practice assignments. Based on their participation in class, asking Simon for clarification and answering Simon's questions about the content, the students appeared to be motivated to learn and to develop an understanding of the content of the course. The students seemed to be actively engaged in the learning process, working with Simon and their peers to master the skills and concepts of each lesson.

Additionally, Simon explained that students have developed new perspectives on math. For example, Simon described a particular project that allowed for differentiation, where students built a train out of shapes and then created formulas to calculate the perimeter and length of their trains. Even if groups chose to use the same shape, the assembly of the shapes varied from group to group, and the final products were different. Simon stated, "They'll start arguing with each other that theirs is wrong, and then once we actually start reading the directions and talking…they start realizing there are multiple ways or different ways to do things" (1st interview, January 2018). This statement illustrates how students were exposed to other students' perspectives and use the knowledge gained from various exercises, such as the project described above, to build a deeper understanding of the mathematics concepts from newly evolved perspectives of their own. According to Simon, students found strategies that made sense to them, including the use of certain technology, and used those strategies going forward. The exposure to different perspectives and strategies allowed Simon to reach students with different backgrounds and viewpoints, contributing to the differentiated instruction in Simon's classes.

Analysis of Contradictions within Simon's Activity System

Multiple contradictions and tensions were identified within this activity system. During one of the interview sessions, Simon described a secondary contradiction that arose between the one of the tools – the online textbook practice website - and the object of the activity system, shown in Figure 6 as contradiction A. In this specific situation, Simon had developed an extra credit activity for students to complete using the textbook's website; however, the online textbook was not functioning properly due to website maintenance, and one of his classes was unable to access the activity. Simon could not use the online textbook tool to accomplish his goal of improving student learning and engagement. Simon stated:

> It's what they always told us in our teaching classes: be prepared for the unexpected. So I still have paper and pencil stuff all the time if that happens…you have the best of intentions, but you can't plan for those things; they just happen. (2nd interview, April 2018)

Simon worked through the tension created by this contradiction by modifying his plans for that class period and allowing these students to complete the activity the following day. A similar secondary contradiction had occurred earlier in the year with some teachers having issues with connecting Chromebooks to the internet. The school system worked to re-establish the internet connectivity so that teachers could use these tools to support their instructional goals, and Simon explained that, for the most part, internet connectivity was no longer an issue. Simon depended on the accessibility of the internet and online resources to provide opportunities to differentiate instruction and meet his students' diverse needs; however, Simon also recognized the importance of planning for obstacles that may interfere with the use of technology in the classroom and being flexible in the cases that technology does not work as planned.

Other obstacles sometimes prevented students from using Chromebooks in Simon's classroom in the secondary contradiction between the educational technology tool and the object of promoting student learning. For example, Simon explained that there was typically a span of time at the beginning of the school year where time had to be spent setting up students' accounts and passwords and making sure students can access all of the necessary resources. He communicated:

> The biggest issue we have is at the very beginning of the year, basically, just getting everybody established with their accounts and everything and setting up their passwords and then having those in a place where they can access them. But usually after probably about the first three or four days, we get all that worked out, and then, once that first week's over, they're pretty well-established. (2nd interview, April 2018)

Simon also described instances where students transferred into the school district and did not have online accounts immediately when they began classes at Actin High School, explaining:

> The only other issue is when you have new students who come in who don't have accounts, and it's a couple of days before they get it. Then they're behind, and it's tough on them, especially kids who come from systems that maybe don't use a lot of technology. There's a little learning curve for them. (2nd interview, April 2018)

These differences contributed to the unique learning needs of the students in Simon's classroom, creating an even greater need for differentiated instruction to maximize learning opportunities for his students.

Some of Simon's students used the Chromebooks for nonacademic purposes. This primary contradiction, designated in Figure 6 as contradiction B, resulted from the double nature of the educational technology tool, where it functions both as an academic tool and as a distractor for students. Simon explained, "they will stray off the website that they are supposed to be on…I don't mind them necessarily Googling or searing for things to help them, but you still have to walk around and monitor that that's what they're searching" (2nd interview, April 2018).

Simon also described having students who, for whatever reason, chose not to do the assigned work. Simon stated:

> You have students who, when you give them that time, will choose just not. Again, it's kind of an individualized pacing. You can't stand over every kid and put your thumb on them and make them do [the work]. So I have some that just won't stay with it, and so they'll turn their music on and still have the page open, but they won't actually do the work. (2nd interview, April 2018)

In this secondary contradiction, the students were not taking on the responsibilities and performing the tasks within their division of labor, which conflicted with the teacher's expectations and goals of students actively engaging in classroom activities and completing assignments. This contradiction is shown in Figure 6 as contradiction C.

Case 3 Summary: Coherences and Contractions

Simon, the subject of the activity system in this case, engaged in the activity of teaching mathematics. Simon's goals and motives, or activity system objects, included motivating students, improving student learning and engagement, and preparing his students for future mathematics courses. Simon also wanted to help students enjoy math by exploring different perspectives related to the content and integrating technology into the class.

During engagement in this activity, Syrus used numerous tools, including his pedagogy and beliefs as a teacher, assessments, and multiple forms of educational technology. Simon, the students, and Simon's colleagues shared responsibilities and took on various roles as part of the activity system's division of labor. Simon took on the role of facilitator within the classroom, and collaborated with other teachers on how to best integrate technology in the classroom and how to effectively teach the content required for students to be successful in their current and future math courses. Students collaborated with their peers and gave Simon feedback on their progress and mastery of the content, taking on roles as both teachers and learners during class. The outcomes of this activity system included student learning, motivation, engagement, and development of new math-related perspectives.

Sometimes, the educational technology did not function properly, as seen with the online textbook website example above, which caused tension between the use of the tool in achieving Simon's goals for the class. In another contradiction, the educational technology had the potential to be misused by the students, hampering the achievement of the object of the activity system. Some students did not perform their responsibilities as part of the division of labor, conflicting with Simon's teacher-generated goals. The components and contradictions of this activity system are compared to those of the other cases' activity systems in the cross-case analysis at the end of this chapter.

Case 4: Syrus

Professional Background and Present Experience

Syrus is a STEM teacher at Actin High School. His highest level of education is an Education Specialist degree in Leadership Education. Syrus has 19 years of teaching experience in a wide range of grade levels and subjects, including elementary education, 8th grade Science, and high school STEM. Syrus's high school STEM classes included students in grades 9 through 12.

Syrus explained that his experience as an elementary teacher actually sparked his interest in STEM because he was able to see the connections between each subject level. He stated:

> In elementary school, you have to teach everything…I think that's probably what drew me to STEM is being an elementary teacher and having to teach all of the subjects and realizing that you could teach language arts through history studies, and, through science, you can find literature. I think it was kind of embedded in the elementary mindset. That's how you teach. And the older kids get, the less that happens, and, having the STEM movement come along, I felt like that's tapping into what I, as a trained elementary teacher, was taught to do" (1st interview, January 2018).

This statement reflects Syrus's belief that academic subjects become less connected as students progress into higher grade levels. According to Syrus, STEM unites multiple disciplines to solve problems, which was what he found appealing in teaching both elementary grades and STEM courses. With the STEM education program at Actin High School, Syrus taught some of the same students for up to four years, allowing him to experience his students' evolution and maturation throughout their high school careers.

Activity Systems Analysis: Syrus

Subject and object. As shown in Figure 7 below, the subject of the activity system in this case was Syrus. Syrus's goals and motivation, which make up the object of the activity system, consisted of using a multidiscipline approach to develop his students' problem-solving skills. In these STEM courses at Actin High School, Syrus wanted to help students "grow and develop life skills and classroom skills to be successful in solving problems," by building foundational knowledge and practice combining multiple disciplines, such as science and math (1st interview, January 2018). Furthermore, Syrus wanted his students to utilize and build upon this knowledge to be able to creatively solve problems in their future work environments. Syrus also worked to help his students develop collaborative skills in preparation for future experiences in the workplace.

Tools. Multiple tools were identified in this activity system, including Syrus's pedagogy, teacher beliefs, classroom management strategies, professional development, educational technology, funding, and assessments. Each of these tools is discussed in more detail below.

Pedagogy, teacher beliefs, and classroom management. Syrus encouraged a collaborative, positive learning environment in his classroom, which was influenced by his beliefs as a teacher and his pedagogy. This emphasis on positivity and collaboration also facilitated Syrus's classroom management, as students worked together to accomplish a common task, with few disciplinary issues. Syrus did not focus on students' individual grades; instead, he aimed to help students recognize that they could work as a team to solve problems. Syrus communicated:

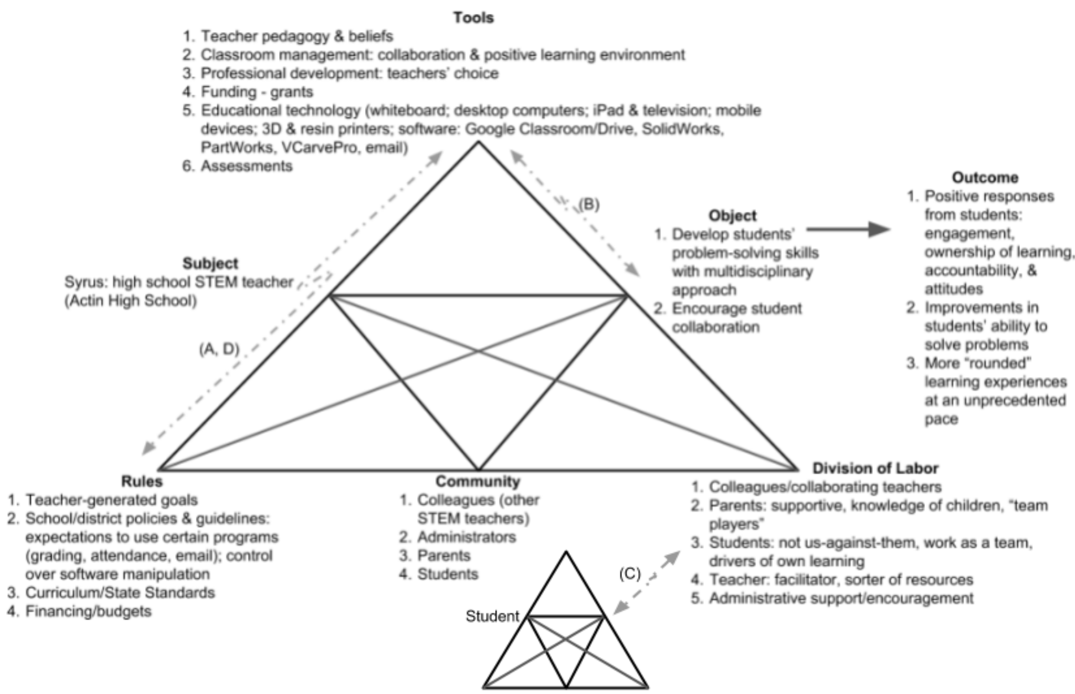

Figure 7. Triangle model of the activity system in Case 4. This figure illustrates the components of CHAT that were identified during Syrus's engagement in the activity of teaching STEM.

> I think getting positive response back from your kids, engagement, attitudes…I also feel like when kids recognize that it's not them against everyone else, but they can almost work as a team and help each other solve problems. Because in a real work environment, it's rarely us-against-them. It's we're all in this together so if I've got a skill that I can lend to this other person or this group, that's what I want to do. So I tell them grades are not important to me. That's between you and your family, you and your college applications, but if you understand how to do the things that I'm trying to teach you, that's going to last a lot longer than whether you got a B or an A in this class. (1st interview, January 2018).

Syrus believed this approach better prepared students for what they would eventually experience in a real work environment.

The integration of technology and differentiated instruction was also important to Syrus's beliefs as a teacher. He explained:

> I only foresee things being much more intertwined when it comes to experiences and technology being involved, whether it's virtual reality or just having immediate access to information. I think those things can only improve differentiation for educators, in general, and students. (3rd interview, May 2018)

This statement illustrates Syrus's beliefs about how educational technology can be used to aid in differentiated instruction to the benefit of the students and meet their individual learning needs.

Professional development. Syrus communicated that professional development had the potential to help teachers work toward their goals, especially when teachers were allowed to choose the content and focus of this professional development. He suggested:

> I think our school is trying to address this a little bit, and maybe it's my department as well, allowing educators to choose things that pertain to them and their coursework and what's important to them as an educator. I think they'll be more motivated to make positive change as opposed to just having in-service days of a general nature that maybe don't apply to everyone. Like if I've got some equipment out here that shows up, well, I may spend a ridiculous amount of time trying to figure it out through resources I can come up with. But if I could…go to a particular training for a solid day on this, this would save us all a lot of headache, and I think I'd be able to implement that better in the classroom as far as an educational tool. (3rd interview, May 2018)

Syrus appreciated when teachers were allowed to select the professional development that would benefit their instruction the most, based on the specific needs of each teacher and their students. The school also periodically held school-wide in-service days based on differentiated instruction, which Syrus believed helped "reinvigorate or at least put some things out there that are beneficial" for teachers to implement in their classrooms and potentially make a difference in the kids' lives (3rd interview, May 2018).

Educational technology. Educational technologies were recognized as tools in this case, including numerous forms of hardware and software. During whole-class instruction, Syrus used an iPad to project onto a television at the front of the computer lab portion of the classroom, where each student had access to a desktop computer. The classroom also had 3-D printers and resin printers for students to use, along with several STEM-related software programs, such as SolidWorks, PartWorks, and VCarve Pro. Syrus explained:

> It would be very difficult to do a lot of the things we do in here without access to technology…there's a computer lab that's here everyday. Communicating for research, communicating for design, being able to have these computers talk to machines out there, is necessary…I think without that then you become less of a STEM [classroom] and more of a shop. (1st interview, January 2018)

According to Syrus, educational technology provided increased accessibility to a wider range of resources, which improved student accountability as well as differentiation. Technology also enhanced communication between Syrus and his students. For example, while Syrus was at a robotics tournament, he was able to answer students' questions via email, provide them with additional resources on Google Classroom, and even light-heartedly prank his students on a Friday afternoon by "Rickrolling" them, providing students with a link that was supposedly a 3D printing resource but giving them a link to Rick Astley's song "Never Gonna Give You Up" instead (2nd interview, March 2018). Syrus described the convenience of students being able to access content from their own mobile devices at home, using software such as Google Drive to store and work with files from any device with an Internet connection. Technology afforded students the ability to review resources as many times as they need to, as well as to find new resources of their own, which improved the pacing and efficiency of the class.

Funding. Funding was essential in Syrus's technology-rich classroom. The financing and budget of the school and district were rules in this activity system because they placed certain restrictions on what Syrus could purchase for his classroom; this aspect of financing is discussed in the Rules section below. On the other hand, Syrus had also written grants to obtain resources outside what could be provided by the school system. Syrus stated:

> Many years ago, I was writing grants to get technology in the classroom. I probably had the very first classroom [Promethean Board] in the entire system because I went out and found some money for it. It's just something I've always though, why not? The kids are certainly more interested in this…As far as STEM goes, it's kind of like a playland for me in that I get to have a classroom full of computers for lots of things, equipment that otherwise in a regular classroom I'm not going to have access to, nor will the kids. I think my personal drive to et the next best thing, in terms of classroom things, can only be good for the kids. (2nd interview, March 2018)

In these cases, the money would be considered a tool that Syrus had used to purchase other tools for use in his classroom, such as new equipment that he felt would benefit his students.

Assessment. – Syrus employed various forms of assessment to gauge students' understanding. The use of digital assessments was specifically mentioned when Syrus said:

> If I can formulate an assessment through digital means, it gives me data instantaneously. It gives me hopefully accurate data. Obviously, I have to put in the time to put the right

> things in to get what I need. This certainly speeds up the post-data collection part of it. (1st interview, January 2018)

Syrus used Google Forms to deliver formative assessments, including quick questions and exit tickets, which allowed Syrus to look at the data with the students to review concepts, generate class discussions, and discover knowledge gaps and misconceptions. Syrus also used more formal and summative assessments, such as quizzes and tests, in order to "have some concrete data on whether [the students] were successful at learning all of the required objectives for the particular unit" (3rd interview, May 2018).

Community and division of labor. The community in this activity system included school administrators, parents, and students. In the activity's division of labor, these activity participants shared certain responsibilities and took on different roles. School administrators provided support and encouragement to the teachers with regard to their teaching approaches and integration of technology into their classrooms, which also served as a basis for some of the rules in the activity system, addressed below. Syrus described this support and encouragement, stating:

> I think our system adopting certain software like what we use for grading and attendance, Google Drives, web-based email, those sorts of things are inherent within the school system that I think encourage teachers to use them. Now, how, to what extent is on them probably at this point. But I do feel like administratively there's some encouragement…I would imagine they're still looking for integration of technology and, of course, how does that affect individual students? (2nd interview, March 2018)

Syrus explained that the parents' responsibilities included being invested in their child's learning and "having a realistic view of how their kid learns and what their strengths and weaknesses are and…being a team player" (3rd interview, May 2018). Syrus went on to explain that, ideally, he could better differentiate instruction to promote learning in the classroom if "educators, parents, community, everyone down to the custodian, [had] some awareness" of how students learned and what they needed. (3rd interview, May 2018).

Syrus described his role as a STEM teacher as more of a facilitator; he said, "I tend to point them in the direction of resources and get to question things that they're doing, but mostly prod them into growing themselves" (1st interview, January 2018). When he taught middle school science, he felt his role was more of a lecturer and leader, but the curriculum and structure of the STEM course allowed him to take on a more facilitative role.

According to Syrus, many students came in before school, after school, and in between classes to put in extra effort and improve upon their projects, indicating that students were really invested and engaged in the class. Syrus described the student's active role in the classroom by saying "they're the primary driver of their learning…I typically give them the materials and say you're going to need to know this to be able to do this" (1st interview, January 2018). Students were often given a choice in the instructional decisions and activities that occurred in the classroom, and, according to Syrus, this aspect of student choice was even built into some of the course standards. For example, students were required to display their knowledge of a certain topic as specified in the state standard; Syrus let the students choose the format, such as a written report, an oral presentation, or a hands-on demonstration, to show their understanding or mastery of the content and skills associated with that state standard. The setup of the class and the educational technology actually "allows the kids to become teachers themselves" (1st interview, January 2018).

Rules. Syrus's engagement in this activity was guided by multiple rules. In addition to teacher-generated goals and expectations, there were state standards that Syrus had to address throughout each of his STEM courses. These standards outlined skills and concepts that students should master during the course, but they also allowed for some flexibility in how students show mastery. Syrus even believed that the state standards for his course contributed to differentiated instruction by affording a certain degree of student choice, claiming, "Some of the standards themselves are written that way. You can do this, this, or this to show that…giving kids the option to choose which one they want" (1st interview, January 2018).

As previously mentioned, budgets provided by the school or district contributed to the rules when they regulated what Syrus could purchase for his classroom. The school district also controlled who was allowed to make certain changes to the software and hardware throughout the district, which sometimes caused tensions when Syrus needed to manipulate or alter certain aspects of a technology, as discussed in greater detail below. Furthermore, there were expectations from the Actin City School district related to the integration of specific technologies in the classroom. Syrus explained:

> Our system adopting certain software, like what we use for grading and attendance, Google Drive, web-based email, those sorts of things are inherent within the school system that I think encourage teachers to use them. Now, how and to what extent is on [the teachers] probably at this point, but I do feel like administratively, there's some encouragement. (2nd interview, March 2018)

Syrus communicated that, although he was not an evaluator of other teachers and there was not exactly a firm or strict district policy on technology use, he believed the administrators were looking for teachers to integrate technology and to explore how that technology integration affected individual students.

Outcomes. Multiple outcomes, or results, were identified in the activity system of this case, including what Syrus perceived as various positive responses from students. Syrus explained that, as a result of integrating technology and applying his multidisciplinary approach, his students were engaged in mastering the course content, and students took greater ownership of their own learning. Syrus claimed that technology "really adds accountability to [students] that they don't have excuses for not having something done or turned in on time" (2nd interview, March 2018). He also observed students "leaving with good positive attitudes about what they've done and maybe a possible future for them" (1st interview, January 2018). Furthermore, students exhibited improvements in their ability to solve problems. Even though the use of the Internet was not new or cutting edge, Syrus indicated that the integration of the educational technologies described above helped students have learning experiences that were "much more rounded at a pace that [was] unprecedented" (1st interview, January 2018).

Analysis of Contradictions within Syrus's Activity System

Syrus described certain conflicts, or contradictions, that arose while engaging in the activity of teaching his STEM courses. When asked about the challenges of using educational technology to reach diverse learners in the classroom, Syrus responded:

> The challenge for me is there's so much out there, technologically speaking, and it moves so quickly. For me, trying to weed through what is going to be new or useful and not antiquated and not useful…and being able to weigh whether the expense is worth it. We've made investments in things that seemingly, this is the next big thing; if it's not supported in two years, we've got hardware, for example, that is a rock, and we've just wasted money. So most of my plan time comes down to researching how to use some technology to decide whether that's something I need to invest in or projects that I need to

> be trying to figure out ways to fund or work through the class. So my biggest challenge is money, keeping up, and there is a ridiculous amount of resources out there... (2nd interview, March 2018)

There are multiple secondary contradictions within this statement. First, one secondary contradiction existed between the tools of available educational technologies and the rules related to financing and monetary expenditure, shown in Figure 7 as contradiction A. Syrus described having to choose which forms of technology provided the greatest sustainability of educational benefits, while still operating within the financial limits of imposed budgets for classroom spending. Syrus responded to the tension created by this contradiction by investing time into researching various available technologies in an effort to make the best instructional decisions about what forms of technology to purchase and utilize in his classroom. A second contradiction existed between the educational technology tools and the objects, or goals, of this activity system, represented as contradiction B in Figure 7. Syrus believed that he had to sort through the vast amount of available technologies to decide which would best enhance student learning and engagement, rejecting the forms of technology that would not serve to meet his goals, or, in other words, the objects of this activity system.

A quaternary contradiction was identified between the division of labor within Syrus's activity system and neighboring activity systems, displayed as contradiction C in Figure 7. More specifically, the students themselves were the subjects of neighboring activity systems, which influenced students' engagement in activities inside and outside of the classroom, and each of these activity systems included its own unique components (e.g., tools, rules, and objects). The students, who were part of the community in Syrus's activity system, had experiences outside of the classroom that sometimes affected their ability to take on the responsibilities within the division of labor of the classroom. In the second interview session, Syrus communicated his belief that students come into the classroom with different experiences and "social and cultural issues that [he could not] fathom." He elaborated:

> If you've got a kid, for example, whose mom died last week, the last thing that kid is trying to think about is how the physical dynamics of momentum work, but I know for him to move forward on a particular project, these are things he has to get, and I can't change those things. I can't change what happened at home. You can only work with that and try to move them forward. (2nd interview, March 2018)

Syrus explained that some students may live in homes where certain necessities and resources, such as food and electricity, are not always available. According to Syrus, "those human situations play a role in whether they have access, whether they have the drive" (2nd interview, March 2018). In these instances, the factors that were external to the classroom activity system may have negatively affected students' motivation and ability to perform academically, which could, in turn, impede student learning and engagement in the classroom.

Syrus also described issues related to having control over some aspects of the technology. This was classified as a secondary contradiction (contradiction D on Figure 7) between the tools and rules activity system components. Syrus explained that the school district's Central Office placed restrictions on who had the authority to make technology-related changes. For example, there were features of the SolidWorks CAD program that Syrus was not allowed to control; Syrus specified:

> I have very limited access to making changes to software. It all has to go up the hill and [I have to] put in a ticket or call someone. Even at the building level, our technology director doesn't always have the access that he needs, for whatever reason that is…We

> run into issues with [having] to have this CAD program today, and it's just not loading correctly, and I hope the right person is in office to be able to push the right buttons. There is this level of trust that isn't there, right or wrong…So that's frustrating for me, in that I can't update a program that needs updating without calling someone. (2nd interview, March 2018)

Syrus communicated that he believed the Central Office had valid reasons for controlling the technology, including the possibility that some people may have previously abused or misused the power to make technology-related modifications in the past with adverse effects. Syrus explained that the technology was all connected via a system-wide network so downloading dangerous software or files, for example, could have serious negative consequences; however, he expressed frustration in feeling technologically competent enough to make good decisions while not having the power to make necessary changes to software in his classroom.

Case 4 Summary: Coherences and Contractions

In this case, Syrus engaged in the activity of teaching high school STEM courses, with the goals or objects of developing students' problem-solving skills using a multidiscipline approach and an emphasis on student collaboration. Many tools were employed by Syrus in the pursuit of these objects, including Syrus's pedagogy and beliefs as a teacher, classroom management strategies, professional development, funding in the form of grants, assessments, and a wide range of educational technologies.

Colleagues, administrators, parents, and students also participated in the community of this activity system, taking on different roles and responsibilities within the division of labor. Syrus met with other STEM teachers, sharing and collaborating about technologies and strategies to incorporate in the classroom. Syrus believed that parents should be supportive "team players" with knowledge and understanding of their children's strengths and weaknesses. Students were expected to become the drivers of their own learning and to work as a team, adopting a positive, collaborative role instead of an "us-against-them" role. Syrus's responsibilities included facilitating student learning and sorting through available resources to find the most beneficial tools for his students. The role of the administration included providing support and encouragement related to the integration of both educational technology and differentiated instruction in the classroom.

Syrus's activity system exhibited a variety of contradictions. The vast amount of educational technology-related resources available and the limitations imposed by budgets created conflict as Syrus had to invest a great amount of time to determine which resources were both attainable and most beneficial for his students. Other rules, such as the district policty that restricted teachers' control over some aspects of technology, impeded Syrus's attainment of his goals. Syrus also identified a quaternary contradiction as students' external activity systems contained components that sometimes interfered with the division of labor in Syrus's activity system. The cross-case analysis at the end of this chapter addresses this activity system as compared to the other cases' activity systems and positions these findings within the context of the research questions of this study.

Case 5: Austin

Professional Background and Present Experience

Austin is a STEM teacher at Myosin Junior High School. Austin has eleven years of teaching experience. His highest level of education is a PhD in Oceanography. Austin has experience teaching 6th grade science, 7th grade science, 8th grade science, biology, environmental science, and currently 8th and 9th grade STEM.

Activity Systems Analysis: Austin

Subject and object. The subject in this case was Austin. The object of this activity system was identified as student learning and mastery of the curriculum as outlined in the standards, as well as helping students earn college credit for STEM-related courses. These activity system components, along with the tools, community, division of labor, rules, and outcome, are graphically represented in Figure 8 below.

Tools. Austin used multiple tools during the engagement in the activity of teaching his STEM courses. These tools included Austin's pedagogy, beliefs as a teacher, classroom management strategies, and assorted forms of educational technology. The following sections address how Austin used each of these tools to pursue the goals or objects of this activity system.

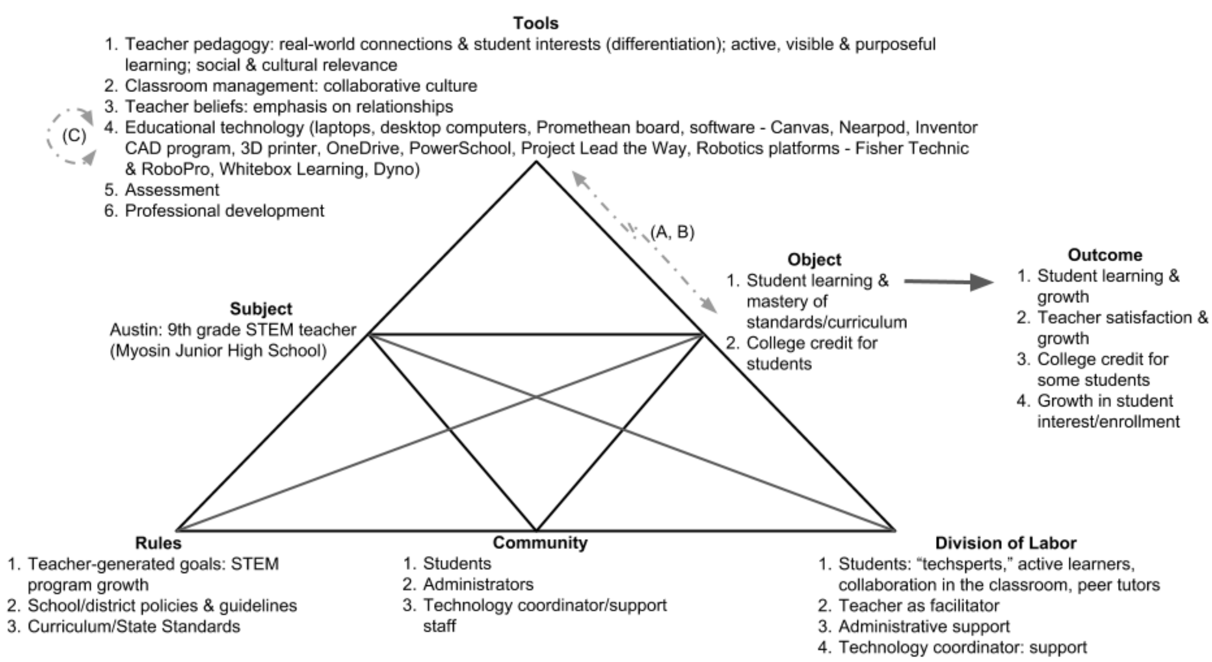

Figure 8. Triangle model of the activity system in Case 5. This figure illustrates the components of CHAT that were identified during Austin's engagement in the activity of teaching STEM.

Pedagogy, teacher beliefs, and classroom management. Austin's pedagogy and teacher beliefs were identified as tools in this activity system. Austin had a particularly strong background in scientific research, and this was prevalent in his teaching beliefs and choices. Austin stated, "I believe in research and literature, and…I want to employ best practices, and, if best practices are changing, then…I want to try to do that" (1st interview, February 2018). Austin described his most recently implemented strategy based on research and literature, utilizing visible learning and daily student reflection questions, that helped to make learning "purposeful and visible" (1st interview, February 2018). He also communicated the importance of presenting content with real-world connections and making lessons personal, appealing to students' interests.

Austin emphasized the development of positive relationships within the classroom, both teacher-student and student-student relationships. In the initial interview, Austin stated, "I think that if there's that trust and there's a strong relationship between the class, the students in the class, and the teacher, that learning can take place" (1st interview, February 2018). The significance of trust, community, and relationships was evidenced by Austin's consistent use of "we" throughout the interviews as he spoke about his teaching and his students. These beliefs and pedagogical choices also contributed to Austin's classroom management, another tool in this activity system. The students in the classroom seemed to have genuine respect for Austin and for each other, and, during the two classroom observations conducted, there were positive interactions and little to no disruptions during regular class activity.

As part of Austin's teaching practice, multiple modes of instruction were used in this classroom, including direct instruction. Austin stated:

> I'm still a believer in direct instruction. It doesn't seem like that model is very popular these days, but, if you ask most of my students, they enjoy when I get up in front of them and teach, as opposed to them learn on their own and…go through this completely on their own. (1st interview, February 2018)

He also explained that he utilized less direct instruction in his current STEM classes than in previous science courses. Austin described his teaching role as having evolved into more of a facilitator of student learning in these project-oriented classes. There was a routine to Austin's class, which began with an introduction where the class discussed the goals of the day and the standards that were being addressed, and then the remainder of class typically consisted of students working on projects, sometimes individually and sometimes in groups of various numbers, depending on the project.

Differentiated instruction strategies were also identified as part of Austin's pedagogy. Austin defined differentiated instruction as:

> getting the same content to all levels of learners and the way you deliver that content has to cater to the individual student…you learn the way they learn, you get to know your students – again, building relationships. You teach the lesson so that all learners have the potential to demonstrate the competencies you're trying to get. (1st interview, February 2018)

Austin differentiated by students' ability levels, sometimes abbreviating assignments for students who showed the necessary skills but who worked at a slower pace. Austin sometimes offered incentives for more advanced students who had completed their work to provide these students with learning enrichment opportunities; for example, if students finished a project early, Austin allowed students to 3D print their designs.

Assessment. Austin provided students with clear direction and explanations of the standards (contributing to the rules in this activity system), as well as formatively and summatively assessed to ensure student understanding. Austin incorporated both formal and informal assessments in his teaching practice, but he also communicated the significance of finding a balance so that students have opportunities to explore and express their own creativity. When asked about the importance and format of assessments in his classroom, Austin responded:

> Now I'm doing a lot of performance-based assessments. Can you do this? Show me a work product, and there's well-designed rubrics that go with it. The students have access to those rubrics, which also goes back to maximizing student learning…If you look at my gradebook, both the formative and summative assessments are usually work products now…You can't tell if someone's learning unless you assess…That can look like a lot of different things. It could be a conversation with the student…it could be work that they submit, it could be a test or a quiz, but the only way in my book to know someone learned is to assess. (1st interview, February 2018)

These assessments and creative opportunities, which appealed to students' interests, also contributed to Austin's repertoire of differentiated instruction techniques. He related assessment and differentiated instruction, stating, "If their assessments are poor, then perhaps I did a poor job of differentiating for that student. If I see that they've excelled by looking at their assessments – formative, summative, projects, rubrics – then…I can make the appropriate changes" (1st interview, February 2018).

Educational technology. Many forms of technology were used by the students and the teacher to accomplish numerous academic tasks. Austin's classroom contained desktop and laptop computers, and, since the Myosin City School district was implementing a one-to-one technology initiative, every student had a laptop that they carried with them to use during class and at home. For example, Austin employed both hardware and software to deliver direct instruction, create rubrics, and provide students with choices and options in personalizing their projects. Students worked with multiple software programs throughout the course, including the Inventor CAD (computer-aided design), Whitebox Learning, the Canvas Learning Management System, the Fisher Technic and RoboPro robotics platforms, and a suite of Microsoft Office programs, including OneDrive, PowerPoint, Excel, and OneNote. Austin explained, "Technology is an integral part of what we do for our standards. For example, they have to do solid modeling and CAD, computer-aided design, so it's essential" (3rd interview, May 2018). These educational technology tools also allowed students to give input and take ownership of their own learning.

Canvas, the school district's learning management system, was vital in supporting student organization and disseminating materials, such as video tutorials. Austin named pacing, when students could work somewhat at their own speeds, as one of the main affordances provided by technology to differentiate instruction. Austin explained:

> It's great because students that are high fliers that really move fast can take control of their learning on their own without me having to go and give them that detailed help, but students that really struggle will watch the video, and they might have to pause; they can rewind it. If they're English-language learners, they can put subtitles on there and read in their native language. And so, for differentiation, it's perfect because they control their pace. (3rd interview, May 2018)

The software, especially Canvas, increased the accessibility of these resources, which was beneficial to students who needed to see content multiple times or in different forms. Canvas also provided opportunities for students who worked more quickly, enabling them to explore more advanced skills and content.

Community and division of labor. In Austin's case, the community consisted of students, technology support staff, and school administrators. Austin expressed interest into expanding this community in the future by becoming involved with his county's Robotics Team.

In the division of labor within this activity system, the participants took on different positions or roles related to the instructional activities of Austin's class. In this 9th grade STEM classroom, Austin took on the role of the facilitator of student learning, and the students were given some autonomy in selecting various aspects of their work while also acting as collaborators with their peers and their teacher. Austin encouraged students to help one another, stating "generally the rule is in the class ask two and then ask me, and so…I can help spread it around and help people faster;" additionally, Austin fostered a spirit of collaboration within the classroom, naming the mantra that everyone in the class was responsible for helping one another (1st interview, February 2018). Students were expected to engage with the material, taking on the role of an active learner and asking questions when there was a lack of understanding. The class also appointed "techsperts," which were students who demonstrated an aptitude for various forms of technology used in the class.

The school's technology support staff provided help when there were issues involving hardware or software that Austin and the "techsperts" could not fix. During one of the classroom observations, one of these software issues arose, and the student was able to visit the help desk and return in a matter of minutes with a resolution. The school's administration provided support, especially to teachers who want to help themselves. Austin described a robotics professional development course that he was planning to attend during the summer; the administration encouraged Austin's efforts, paying for travel and giving him a stipend for attending the course.

Rules. The rules guiding this activity system included teacher-generated goals, the curriculum/state standards, and school/district policies. Austin described one of his goals as growing the STEM program at Myosin Junior High School. He wanted to develop the program so that the enrollment continued to increase from year to year. To accomplish this goal, he tried to create a positive, collaborative environment where students experienced learning and earned college credit by the end of the course, which was also reflected in the object of this activity system.

The state standards made up the curriculum and provided direction for Austin's instructional decisions. Austin explained, "We have state standards, and I make sure I teach the standards so that students obtain competencies under each standard" (1st interview, February 2018). Austin described these standards as "vague and general…so how you interpret that as an educator leaves the doors wide open, and you can do fun, engaging project. You can stay current with them, both socially and culturally current. I can make them relevant" (1st interview, February 2018). Austin interpreted these standards as allowing students some flexibility and choice in the practice and demonstration of their competencies, which contributed to his ability to differentiate instruction in the classroom to meet his students' individual needs.

Policies and guidelines at the school and district levels were also identified as rules in this activity system. For example, the one-to-one laptop initiative itself was implemented districtwide, so there were certain expectations with the use of the available educational technologies in the classroom. There were also expectations that resulted from the activities of the school-based professional learning community. As a member of this professional learning community, Austin was required to read a book on visible learning. The teachers at Mysoin Junior High School were encouraged to incorporate these visible learning strategies into their teaching practice, although Austin did not state that there were any specific strictly enforced guidelines. To incorporate this practice in his own teaching, Austin made a poster to remind his students to reflect daily and explained that "we try to practice these daily student reflection questions in their engineering notebook so that learning becomes purposeful and visible" (1st interview, February 2018).

Outcomes. Multiple outcomes were identified within Austin's activity system. The outcomes of the engagement in the activity of teaching STEM as perceived by this teacher included student learning and growth, as well as Austin's own professional satisfaction and growth. After completing Austin's course and meeting specific requirements, some students earned college credit for STEM-related courses. Another outcome was growth in student interest and enrollment in Austin's STEM program at Myosin Junior High School. Austin said that enrollment in his 9th grade STEM classes for the 2018-2019 school year had increased by forty percent compared to the 2017-2018 enrollment (3rd interview, May 2018).

Analysis of Contradictions within Austin's Activity System

Various contradictions and tensions were encountered during Austin's engagement in the activity of teaching STEM. Austin explained that students were not always equipped with some of the basic computer skills, such as appropriately saving files. In this secondary contradiction, represented in Figure 8 as contradiction A, there was a conflict between the educational technology tools and the object of student learning and mastery of the standards. In response to the tension created by this contradiction, Austin worked with students who lacked these basic computer skills and facilitated collaboration among students to teach the proper use of the technological tools in the classroom in order to achieve the goals of student learning, mastery of the curriculum, and potentially earning college credit for the course. Although this conflict is described as a secondary contradiction between the tools and object of this activity system, it also serves as an example of the interconnectedness of all of the components within the activity system. This situation provided an opportunity for student growth, while illustrating the need for the employment of multiple tools (differentiation, technology, and teacher pedagogical knowledge) and the division of labor within the activity system's community.

Austin also argued the importance of using technology only when its application makes sense and supports student learning. Austin expressed concern that some teachers may employ technology just for the sake of using technology, even when it may not be the best tool to complete a particular task or to accomplish a certain goal; this contradiction is shown in Figure 8 as contradiction B. For example, Austin explained:

> Sometimes, we don't need the computer at all. Sometimes, I encourage them to take notes by hand. It's becoming a lost art form, and, as an incentive, sometimes I'll even let them use their handwritten notes on a quiz or something like that to teach them so they learn how to take notes. (2nd interview, March 2018)

Technology was only used on days when it was appropriate for the standard being addressed. As in the previously described conflict, this was a secondary contradiction between the tool (educational technology) and the object (student learning and mastery of standards/curriculum). This contradiction was also seen when the technology was not functioning properly, preventing students from accomplishing necessary tasks. During one of the classroom observations, an incident occurred when a student's CAD software crashed, causing him to lose all of his work;

this student was so frustrated that he had to start the project over again from scratch that he said out loud to the class that he was going to "literally cry" (2nd observation, March 2018).

Austin also found it difficult to provide timely, high-quality feedback on some of the assignments that were submitted digitally, in another facet of this secondary contradiction between the tool and the object. Austin explained that he did not find the feedback and grading utility of Canvas to work as efficiently as more traditional paper-and-pencil methods. In order to facilitate learning and mastery of the curriculum, students needed to receive constructive feedback in a timely manner. In response to this tension, Austin sometimes preferred to print out students' work, writing feedback on the hardcopy to return to students, instead of providing feedback to students in a digital format.

The dual nature of laptops presented a primary contradiction, depicted as contradiction C on Figure 8. The laptops were used as an academic tool, but they also had the potential to become a distraction or facilitator of academic dishonesty. Students sometimes focused on the contents of their computer screens instead of what Austin was trying to communicate to them, and, in these situations, the technology detracted from student learning. Austin stated:

> It's hard when you're giving instructions. When their eyes are focused on a screen, their ears seem to be closed off. And they're not trying to be obstinate or insubordinate; it's just something that happens with people once [their] face is on a screen. It's distracting to other things that are going on, so I have to work really hard if I want them to listen to me. I have to tell them to clam shell and turn and face [me] and make eye contact. (2nd interview, March 2018)

Additionally, Austin gave students the option to create their engineering journals either digitally or on paper, and the two different formats created problems with his plans for digital assessments. To prevent cheating during digital assessments, Austin would deliver the assessment online using the Canvas platform in lockdown browser mode; this mode prevented students from accessing any other websites while the assessment was in progress. Students were unable to access their digital journals while taking online quizzes in Canvas in lockdown browser mode because viewing their journals required another browser window or tab to open their Microsoft OneNote notebooks. As a result of this tension, Austin favored the use of the hardcopy format for students' engineering journals.

Case 5 Summary: Coherences and Contractions

In this case's activity system, Austin was the subject engaged in the activity of teaching STEM. The objects included helping students learn and master the STEM course curriculum, as well as potentially earn college credit for STEM courses. Several tools, such as teacher beliefs, pedagogy, classroom management, assessments, and educational technologies, were employed by Austin in pursuit of these objects.

The members of the community in this activity system were the students, administrators, and technology support staff. These members each had different responsibilities during the engagement of this activity. The students were active learners in the classroom, collaborating with one another and sometimes taking on roles as peer tutors and "techsperts." Austin acted as the facilitator of student learning, providing students with the direction and resources needed to maximize student learning in his classes. Administration and technology support staff provided support with regard to various instructional strategies and the integration of educational technology in the classroom. The rules guiding this activity system were policies and guidelines at the school and district level, the course curriculum as outlined by state standards, and teacher-generated goals, such as growing the STEM program at Myosin Junior High School.

The outcomes in this case were identified as student growth and learning and Austin's professional satisfaction and growth. Furthermore, as a result of this activity, some students earned college credit in STEM-related courses, and there was an increase in student interest and enrollment in the STEM program at Myosin Junior High School.

Contradictions and tensions were also recognized, which influenced Austin's instructional decisions and the outcomes of this activity system. Some students lacked basic computer skills, which sometimes created obstacles in the use of educational technology tools to meet the goals of the activity. Technology did not always facilitate tasks that were previously done without digital means, such as grading certain assignments; in these cases, Austin circumvented the technology, choosing to use more traditional methods. In another conflict, the technology sometimes became a distraction or source for cheating rather than the academic tool it was intended to be. The cross-case analysis of this activity system with those of the other cases is presented at the end of this chapter.

Case 6: Libba

Professional Background and Present Experience

Libba is a 9th grade Biology teacher at Myosin Junior High School. Libba has two Masters degrees – one in Biochemistry and one in Secondary Science Education. During Libba's biochemistry graduate program, she decided she preferred the academic aspect of science over research so she pursued a career in education. Libba has experience teaching high school physical science, environmental science, and biology courses.

Activity Systems Analysis: Libba

Subject and object. Libba was the subject of this activity system, as shown below in Figure 9. The object, or goals, included student productivity and engagement. When asked about her goals for her teaching practice, Libba stated, "Students would be listening. They would be learning…There will be evidence that they're learning through something at the end of the day. They'd be productive and engaged" (1st interview, February 2018). She wanted her students to be actively participating in their learning, and she believed there should be evidence by the end of each class that learning and progress had been made.

Tools. Libba employed various tools in pursuit of the object in this activity system. These tools are discussed below.

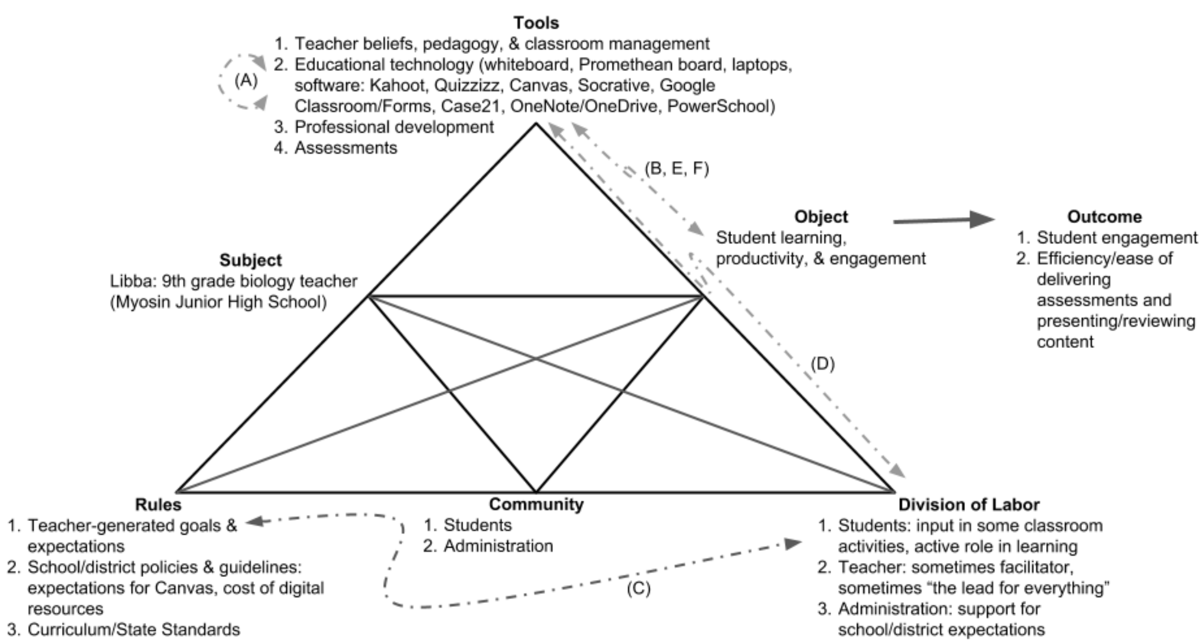

Figure 9. Triangle model of the activity system in Case 6. This figure illustrates the components of CHAT that were identified during Libba's engagement in the activity of teaching Biology.

Teacher beliefs and pedagogy. Libba's pedagogy and beliefs as a teacher were among the tools used during her engagement in this activity. Differentiated instruction was integrated into certain aspects of Libba's pedagogy. Libba utilized technology, another tool, to incorporate differentiation strategies during class to meet the needs of diverse learners in the classroom, as described in the next section. Frequent assessments, both formal and informal, also served to help Libba differentiate and adapt instruction. Libba gave the following example:

> The exit tickets would be used to [identify] if there's something that I think we may be struggling on and adapt what I was planning to do the next day based on the responses and how well they may have done on certain items. (3rd interview, May 2018)

Libba explained that she tried to maximize learning in the classroom by providing students with a variety of resources that would meet the needs of students' various learning preferences; Libba said, "I think it helps to use lots of different resources, whether digital or not: hands-on things, direct instruction at points, things that get them actively involved in some form or fashion" (1st interview, February 2018). Libba also employed flexible grouping as another aspect of differentiated instruction, grouping students by ability level, sometimes heterogeneously and sometimes homogeneously.

Libba also valued student input in making instructional decisions. According to Libba, students sometimes provided feedback about the types of activities they wanted and needed to learn in the classroom. For example, students have asked for a study guide or Kahoot in preparation for an assessment; Libba used this student input to help determine future assignments and activities for the class.

Educational technology. During classroom observations, I observed Libba integrating multiple forms of hardware and software in the classroom. For example, Libba utilized a Promethean Board and her own computer during direct instruction and to facility classroom discussions and deliver some formative assessments. Each student used a laptop during class to access a variety of websites and software, including Kahoot, Quizziz.com, Canvas, Socrative, and Case21. Additionally, for Libba's class, students used both Google Classroom and other Google-associated software, as well as the Microsoft Office Suite of programs, such as OneNote and OneDrive. PowerSchool was used as the grade management system for the school district, so this was used by both Libba and the students to access students' grades on assignments.

Differentiated instruction strategies in Libba's classroom were enhanced by some of the above educational technologies. When asked about how technology was used to differentiate instruction, Libba explained:

> At the end of class if we have, for example, an exit ticket or if we do a digital assessment in some form, like a quiz or Kahoot or something, and students make a particular score, from that point they can branch out and do different assignments based on whatever grade they earned on that. It may be an online assignment, may be a paper assignment, it may be different. But at least that gives you a quick sense of feedback in terms of where they stand. (2nd interview, March 2018)

These assessments are discussed further in the next section.

Assessments. Libba explained that she looked to assessments to serve as evidence of student learning. These assessments took many forms, including both formative and summative assessments. She stated that she tried to assess the students in some way every day. Formative assessments included exit tickets and online Kahoot games. Students were also given online quizzes (using Socrative.com), unit tests, and benchmark assessments. These assessments helped Libba adjust assignments for students based on their ability or readiness levels. More specifically, Libba used students' scores on exit tickets, Quizzizz games, or other formative assessments to determine the nature and depth of subsequent assignments. While these formative assessments informed Libba's instructional choices while students were learning the material, summative assessments allowed Libba to gauge students' mastery of the content at the end of each unit and at various points during the school year.

Community and division of labor. Libba did not act in isolation within the community of this activity system – she also interacted with students and administration. Libba communicated that her role in the classroom should be facilitative, but this role changed depending on the students in the class. In classes made up of students who took initiative for their own learning, Libba stated that she acted more as a facilitator. In classes comprised of students who took less initiative in their learning, on the other hand, Libba said "you [the teacher] are the lead for everything, you hold all the content knowledge, and the job is…trying to spell that out to students" (1st interview, February 2018). Libba described the students' role in the classroom as active, explaining that students should "be involved in the process, be aware of what the responsibilities are, and [put] forth some effort in trying to get to that point where they're learning the actual material" (1st interview, February 2018).

Although Libba did not specifically mention the administration as part of the community, she alluded to their involvement when she spoke of certain support for expectations regarding the use of educational technology, discussed below in the "Rules" section. Libba also mentioned that the administration provided professional development opportunities to expose teachers to new technologies, such as software and websites, that they could incorporate into their own teaching practices.

Rules. Libba described various rules that guided her instructional decisions. The school district and Myosin Junior High School had certain expectations related to teachers' use of certain educational technologies as part of the one-to-one technology initiative. For example, teachers were expected to post assignments and due dates on the calendar of the district's learning management platform, Canvas, in a timely manner; however, there were no strictly enforced time limits or minimum amounts of data or information that had to be provided. Libba specified:

> We are required to post as much as we can to Canvas. I've not been given a specific requirement that every document needs to be posted because I think the district's aware that that's not always going to be an option, depending on what we're using. But assignments always have to be posted to the calendar in a timely manner of sorts. I would assume, as long as you get it on the day that it's assigned, it's probably fine. (2nd interview, March 2018)

According to Libba, teachers were given a fair amount of autonomy to decide the frequency and content of what was posted to Canvas. Additionally, there were other software programs, such as Case21, Nextra, and PowerSchool, that teachers at Myosin Junior High School were required by the district to use for benchmark assessment and grading purposes.

The district also regulated the digital resources that teachers were allowed to use based on cost. Teachers were typically only allowed to use free resources, unless the district approved and purchased specific licenses for a program, like Case21. According to Libba, teachers were generally not allowed to purchase software on their own.

The rules in this activity system also included the Biology curriculum as outlined by the state standards. Libba employed an assortment of tools, such as the previously mentioned Case21 test preparation software, daily instructional activities, and assessments, to review the required course content described in these standards and to prepare students for the state-mandated end of course exam.

Outcomes. As a result of the Libba's engagement in the activity of teaching Biology, various outcomes were identified during the data collection process, such as student engagement during class activities. For example, I observed students displaying excitement and enthusiasm during an online Kahoot review game. During the second interview session, Libba also described the improved efficiency that was afforded by the use of educational technology in the classroom. She explained that programs, such as Socrative, Kahoot, and Google Classroom, allowed her to quickly and easily create and deliver assessments; furthermore, these programs provided Libba and her students with "a quick sense of feedback in terms of where [students] stand" (2nd interview, March 2018). She claimed that using these digital resources allowed her to present content in different ways and to assess students' mastery of content in a more timely manner compared to using more traditional pencil-and-paper methods.

Analysis of Contradictions within Libba's Activity System

The educational technology conveyed a double nature in Libba's Biology class, illustrating a primary contradiction within this activity system. This contradiction is illustrated in Figure 9 as contradiction A. The students' laptops were intended to be used only for academic purposes; however, there were multiple incidents of students misusing their devices. For example, students were observed using their laptops to access noneducational videos on YouTube while they were supposed to be listening to Libba's instruction (1st observation, February 2018). During that same class period, another student was accessing content on his laptop that distracted other students so much that Libba had to stop instruction to inquire about what was on the student's screen. Libba also described a Microsoft-based program, OneNote, where students had the capability to chat with one another. While this technological tool was intended to facilitate collaboration, it also provided opportunities for students to cheat or communicate with one another about unintended nonacademic topics. To further complicate this matter, Libba said that the Microsoft representatives were unable to remove this chat feature, so students were able to essentially text one another during class when they should have been paying attention to instruction.

A secondary contradiction was identified during one of the observations in Libba's classroom. A student's laptop was not functioning properly, and the school's technology helpdesk was closed. The tool (educational technology) was momentarily unable to facilitate the achievement of the object (student learning and productivity), as shown in Figure 9 as contradiction B. In response to this conflict, Libba instructed the student to write her responses on a sheet of paper and transfer them into her OneNote notebook at a later time.

According to Libba, this was not the only time technology had failed or did not work as intended. Canvas, the online learning management system, has the capability to sync to the teachers' online gradebooks. Libba said she had not personally tried to sync Canvas to her gradebook, but she recalled other teachers' experiences in trying to do so. Initially, Libba explained, the teachers were excited about this aspect of Canvas. The teachers later discovered that errors had occurred during the syncing process, and they had to go back and manually correct these errors in their gradebooks. Additionally, most of Libba's assessments had a written response component that had to be manually graded, so this syncing function was not very helpful to Libba anyway since Canvas could not generate grades for that portion of the assessment. All of these instances fall under the conflict of the educational technology tool and the object of the activity system, as in the previous example of loss of OneNote functionality, and are also denoted as contradiction B in Figure 9.

Libba described another secondary contradiction when problems arose during student collaboration in her classroom. In this contradiction, illustrated in Figure 9 as contradiction C, some of Libba's students failed to perform their responsibility within the activity system's division of labor, as guided by the teacher's expectations, part of the rules component of this activity system. Libba expected students to take an active role in learning and participate in classroom activities, including group work. In describing students' use of laptops for collaborative group work in her classroom, Libba stated:

> It seems like even when I do a digital type of assignment where they get to work with groups, if it's an assignment that's a bit more intensive, that takes a class period or more than a class period, there's going to inevitably be one or two people in a group that decide, "I'm going to shoulder all the work, and I'm going to carry the group," and the others will get on YouTube or do whatever it is they want to do…the problems that you get with group work are going to be the same. (2nd interview, March 2018)

While this further illustrates the double nature of technology as an educational tool and as a distractor, as mentioned above, the secondary contradiction exists as Libba had made clear her expectations, but some of her students did not uphold their responsibilities within the activity system's division of labor.

When asked about the challenges of using educational technology to reach diverse learners in the classroom, Libba described tension caused by the time and effort required to learn and integrate new technology in the classroom and the numerous responsibilities already placed upon teachers, which sometimes resulted in teachers feeling overwhelmed. Libba stated, "I think most [teachers] don't want something added to their plates…because we already use a lot of different things, and it seems like there's always something new coming out" (2nd interview, March 2018). This secondary contradiction between one of the tools – educational technology – and Libba's responsibilities as part of the activity system's division of labor is shown graphically in Figure 9 as contradiction D. Libba explained that, even after spending time and effort in preparation, the introduction of new technology-related strategies in the classroom did not always accomplish the intended goal and was not always helpful in the long run. Teachers already had numerous responsibilities, inside and outside of the classroom, and the integration of new technology was sometimes viewed as applying even more pressure and stress to these teachers' already full "plates" (2nd interview, March 2018). Libba described her perspective on other teachers' incorporation of educational technology in their classes, saying "I don't know that they're going to be branching out and trying all these different platforms to try and integrate lots of different [technology]…it's hard. It's too much" (2nd interview, March 2018). She also voiced feelings of frustration with being overwhelmed by the vast number of resources available:

> I feel like you just get bombarded with all sorts of different things…you get emails and things from all these different random companies. Nobody has the time to go through them all. One may actually be beneficial, but I miss it because it's chaotic. (3rd interview, May 2018)

Libba personally experienced the tension caused by this contradiction, recalling an instance when she had discovered usefulness in an online test bank generator called Interactive Achievement; subsequently, the district decided against using this program because several other teachers did not want to learn and employ this technology in their classrooms. Libba had spent time and put forth effort to learn how to use this online test bank generator, and the district ultimately decided to look into other options, which resulted in the need for Libba to once again adapt her instruction to accommodate these changes. Libba described technology as always changing, and she believed that adapting to these changes would simply be a continuous element of working in education.

The teachers were not the only members of this activity system that were overwhelmed by the integration of educational technology. Libba expressed her belief that the students probably felt even more overwhelmed than the teachers. This tension resulted from a conflict between the tool of the employed educational technologies and the object of student learning, productivity, and engagement, as represented in Figure 9 by contradiction E. The students at Myosin Junior high school attended five different classes a day, and the students had to learn to utilize different software programs for each class. Each teacher used educational technology in their own way and held certain expectations for students' use of the different technologies in their classroom. For example, some teachers delivered assessments on paper, while other teachers delivered assessments online. Some teachers used Canvas to deliver content to students, while other teachers chose to use Google Classroom. The OneNote and OneDrive software programs were adopted differently depending on teacher preference, ranging from consistent, daily use to infrequent or nonuse. In addition to adapting to different programs and formats from one class to another, Libba believed that simply having to remember numerous logins increased the students' "mental load" (2nd interview, March 2018). During the third interview session, Libba again made reference to this contradiction, saying "We try to always use new stuff, but I tend to kind of stick with the same thing because I know it works. And [students] get so overwhelmed with a million different things to have to use that you hate to put more on their plates" (3rd interview, May 2018).

Libba expressed her belief that some of the professional development (PD) she experienced was not beneficial or applicable in her own classroom. Libba stated:

> I think we have a hard time finding good resources in terms of software and things that really do what we want them to do, and I don't know how you go about finding other resources that would be maybe better at doing what they need to do. I don't know if there's a better way to expose teachers to what's out there versus me trying to Google something, but I don't think it's me sitting through PD sessions. (3rd interview, May 2018)

As shown by contradiction F in Figure 9, the tool (professional development) did not promote the achievement of Libba's goals, which included student learning, productivity, and engagement. Libba conveyed a desire to find innovative technology-related strategies to use in her classroom, as well as an uncertainty in how to most efficiently discover effective, new technologies.

Case 6 Summary: Coherences and Contractions

Libba was the subject of the activity system in this case, and she engaged in the activity of teaching high school Biology. Her goals and motivations, or objects, included student learning, productivity, and engagement in class activities and assignments. A list of tools were identified in this case, as shown in Figure 9, including teacher beliefs, pedagogy, assessments, professional development, and a variety of educational technologies.

Students and administration also participated in this activity system, playing various roles within the division of labor. Libba sometimes played the role of the facilitator of learning in the classroom; other times, Libba had to take on a role as more of a leader, overseeing everything when students did not take initiative in their own learning. Students were expected to provide input regarding some of the classroom activities and to take on an active role in their learning, although Libba explained that this was not always what actually happened in the classroom. The school and district administration provided support for the policies and guidelines that were related to instructional strategies and the integration of educational technology in the classroom.

The rules guiding Libba's engagement in this activity were school and district policies and expectations, as mentioned above, and the Biology curriculum as outlined in the state standards. Additionally, Libba generated her own goals and expectations that influenced, and were influenced by, the other activity system components, such as the division of labor and Libba's beliefs and pedagogical tools.

Some of the contradictions encountered in this activity system included students' misuse of laptops, malfunction of technological tools, and failure of some students to perform their responsibilities as part of the division of labor, as described above. Additionally, tension was caused by vast amount of digital resources available and the time and effort required of the teacher to integrate these resources. The results, or outcomes, identified in this case included improved efficiency of delivering content and assessments, as well as student engagement in the class.

Case 7: Marybeth

Professional Background and Present Experience

Marybeth is a 9th grade Biology teacher with twenty-two years of teaching experience. She has experience teaching Physical Science, Anatomy and Physiology, Ecology, Advanced Placement Environmental Science, and Chemistry. Marybeth always had a passion for biological sciences, and, as a child, she even had plans to go to medical school. Ultimately, Marybeth chose to combine her love of science and interest in teaching to become a high school science teacher.

Activity Systems Analysis: Marybeth

Subject and object. The activity system in this case is outlined in Figure 10. Marybeth was the subject participating in the activity of instruction, which included the use of educational technology to differentiate instruction in the classroom. The objects of this activity system included student learning, student engagement with the Biology content, and preparation for future science courses. Marybeth also specifically expressed a desire to prepare her honors students for success in Advanced Placement Biology or Dual Enrollment Biology, a college-level course.

Tools. Marybeth employed pedagogy, classroom management strategies, teacher beliefs, assessments, and educational technology during the engagement in the activity of teaching Biology. These tools are discussed in greater detail in the following sections.

Pedagogy and teacher beliefs. During the interview sessions, Marybeth described some of her pedagogical tools, such as employing multiple teaching styles to appeal to and engage different types of learners in the classroom. She emphasized the importance of providing justification and application of learning the content. She explained that she wanted her students to "really get into the critical thinking part of it, the why…it's pointless to talk about things and learn about things if there's no application" (1st interview, February 2018). Marybeth said she believed in what she described as "layering instruction," where she taught content in greater depth, beyond what was expected by the standards, even though she did not necessarily test students at the same elevated level (2nd interview, March 2018). In Marybeth's opinion, when she taught to the "top kid," most of the students rose to meet the challenge; Marybeth also stated that

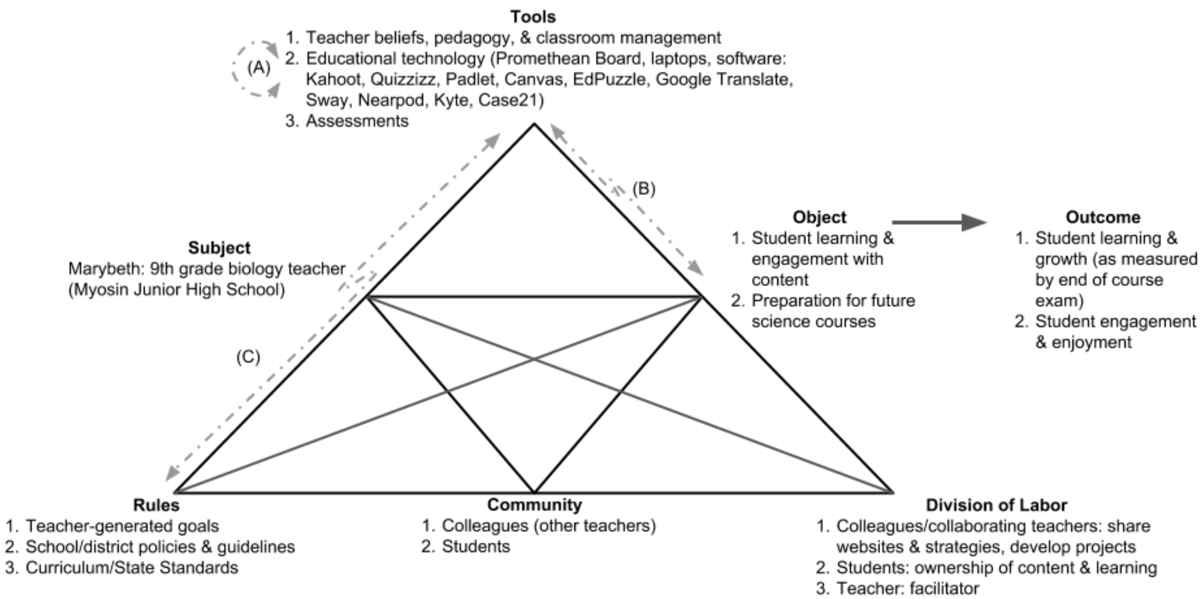

Figure 10. Triangle model of the activity system in Case 7. This figure illustrates the components of CHAT that were identified during Marybeth's engagement in the activity of teaching Biology.

she viewed "layered instruction" and "teaching to the top kid" as valuable preparation for future biology-related courses (2nd interview, March 2018).

Assessments. Assessments took many forms in Marybeth's classes. Student learning and engagement was measured largely by Marybeth's observations of students working and practicing, conversations with her students, and observations of conversations among students. She used these conversations and observations to informally assess if learning was taking place in the classroom. Sometimes, students were ready to move on or move deeper into the content, and, other times, students were struggling and needed to do additional practice or something different entirely. Marybeth often asked students for feedback and gave them opportunities to participate in making decisions about instructional activities and how the class moved through the curriculum. This flexibility and reactivity to students' needs contributed to Marybeth's practice of differentiation in the classroom.

More formal formative assessments were employed almost daily to measure learning in Marybeth's classroom. These assessments included online Kahoot and Quizzizz games and quick pencil-and-paper quizzes. Marybeth also mentioned using the online Padlet program for formative assessment, saying "It is easy to use for a quick formative assessment, to have kids just individually throw what they know up on a quick Padlet" (3rd interview, May 2018). Summative assessments, such as unit tests and benchmark exams, provided evidence of student mastery of content. Data from these assessments was used in making decisions about grouping as well. Marybeth typically arranged students in heterogeneous groups so that students who had a firm grasp on the material could help students who were struggling with the content.

Educational technology. Marybeth utilized technology to differentiate the pacing and level of instructional material. For example, Canvas, the school district's online learning management system, allowed Marybeth to digitally distribute various kinds of materials to her students. Students could access these materials from anywhere, as long as they had internet access and a device that could reach the Canvas website. If Marybeth flipped the classroom and provided her students with an instructional video, students could watch these videos at their own pace, slowing down, pausing, or rewatching as many times as they needed to. Marybeth also explained that the technology allowed her to discretely "dial down" work provided on Canvas for specific students if they were struggling and needed to have the level of difficulty adjusted (2nd interview, March 2018). In another example of using educational technology to differentiate instruction, Marybeth utilized specific websites that could adjust the reading level of the site content to meet the needs of diverse students in the classroom, such as students who were English language learners. From Marybeth's experience, the digital work helped address the language barrier that could cause some students to struggle with material presented in the textbook or during lectures.

In speaking to the pedagogical demands of using educational technology for differentiation in the classroom, Marybeth emphasized the need for teacher preparation on the front end. Marybeth explained:

> It [using educational technology for differentiation] sure is helpful in the long run, but, in the short run, you have to do your homework with it as a teacher. You have to get in there and really involve yourself in it and figure out how it works. (3rd interview, May 2018)

According to Marybeth, putting in the time and effort to prepare to use educational technology could benefit students and allow teachers to reap the rewards over time.

Community and division of labor. The community of Marybeth's activity system included her students and collaborating colleagues. According to Marybeth, the role she must assume as teacher varies depending on where the class is with the content. Sometimes, she is "a true teacher…delivering information," and, other times, she is a facilitator (1st interview, February 2018). Marybeth described this facilitator role, stating "Frequently I'll have them do as much of the concept early on as possible, and then I'll go in as teacher and…make sure that they have it all and they're not going to fall through on any given concepts" (1st interview, February 2018). Marybeth said that she believed in fostering student ownership of the content and their own learning. When asked how she maximized learning in the classroom, Marybeth stated:

> Very frequently by letting my kids go as far as they can on their own without me…they got themselves there, and then I can throw in the rest of it or the depth beyond where I had asked them to be. (1st interview, February 2018)

This statement elucidates the division of labor within the classroom, where students took on an active role while Marybeth took on a facilitative role, while also illustrating Marybeth's application of her pedagogical understanding of students' zones of proximal development.

Another aspect of the division of labor in this activity system was collaboration with colleagues. Marybeth explained that the teachers at Myosin Junior High School shared websites, projects, and strategies that they had found useful in their own classrooms. Marybeth gave a specific example of a multidisciplinary approach she developed with an English teacher. Students explored stem cell research and built arguments using online argumentative writing resources identified by Marybeth's colleague. Marybeth then held a "Stem Cell Senate Subcommittee Hearing" where students presented their arguments and counter-arguments to the class.

Rules. The state's Biology standards contributed to the rules guiding Marybeth's engagement in this activity system. Marybeth described the Myosin City School District as "test-driven" and "standards-driven" (1st interview, February 2018). She went on to delineate the influence of these standards in her own teaching by saying, "Of course I cover the standards, but it's not my North Star when I'm teaching Biology…they influence what I teach, not the way I teach it" (1st interview, February 2018). She acknowledged the significance of the standards, explaining that teachers were judged heavily on students' scores on state tests. Marybeth also explained that in order to prepare students for future science courses, such as Advanced

Placement or Dual Enrollment Biology, she must teach "way beyond" the state standards (2nd interview, March 2018).

Outcomes. One of the results, or outcomes, of this activity included student growth as measured by the state-mandated end of course exam. Marybeth stated, "My kids scores are very high; even with my top kids, I always get good growth" (1st interview, February 2018). Marybeth also described student enjoyment as another outcome of the classroom activities (1st interview, February 2018; 2nd interview, March 2018); students were also actively engaged during various exercises during the classroom observations.

Analysis of Contradictions within Marybeth's Activity System

Numerous contradictions and tensions existed within and between the components of the activity system in this case. A primary contradiction was identified in the dual nature of technology as both an educational tool and as a source of distraction, illustrated in Figure 10 as contradiction A. Marybeth stated:

> The biggest challenge is keeping kids focused. We've tried doing things like using Dyno, which is where I can see where they are – my screen will show me thumbnails of where each one of my kids is. I use it on occasion, but, mostly, they've got phones, they've got laptops, and I would stay that keeping them engaged on a topic can be tough…to keep them where they're supposed to be online and not off and running someplace else. (2nd interview, March 2018)

Marybeth described the usefulness of these forms of technology as an academic resource, but she also explained how students sometimes misused this tool, which could result in decreased on-topic student engagement.

Marybeth also described some difficulties that both the teachers and students experienced as a result of evolving technologies. In this tertiary contradiction, the pre-existing online learning management system, BlackBoard, was replaced with the Canvas online learning management system. During her second interview, Marybeth explained that the transition to the Canvas learning management system was challenging for teachers in the beginning. Teachers had to learn how to operate and set up their classes on this new platform, and then they had to teach their students how to navigate their classes and resources on the new system, all of which required time and effort. Marybeth went on to say that once the transition was made she actually preferred Canvas over BlackBoard. Marybeth also spoke about students resistance to the new online learning management system, stating:

> We switched from BalckBoard to Canvas this year, and you would have thought in the beginning of the year – oh, complain, complain, complain…but as soon as kids started using it, within the first two weeks, they were up and running with it again, and there's been no problems. (2nd interview, March 2018)

Although students initially expressed dissatisfaction about the transition to Canvas because they were unfamiliar with it, they eventually grew more comfortable with using this software.

A secondary contradiction was identified in the conflict between the educational technology tools and the objects within this activity system, which included preparation for future science courses and student learning and engagement with content. This is graphically represented as contradiction B in Figure 10. Some of Marybeth's students were English language learners who enrolled in Myosin City Schools after they had been in the United States for as little as two or three days. Marybeth explained:

> They enroll in school, and they've never had a device ever in their hand. They don't even know how to turn it on. And they don't speak English. They're sitting here with this big device, and they've got no idea how to log on, and then there's the huge language barrier and that can be a big problem. Typically it takes another Spanish-speaking student to put them on [the device]…that takes class time for that student to show the new student how to use it so that can be an issue at times. (2nd interview, March 2018)

Marybeth went on to say that, since this was the fourth year of students using the laptops in the one-to-one initiative, students who were not new to Myosin City Schools typically did not have problems with learning how to use the technology.

Another secondary contradiction was identified as a conflict between one of the tools – teacher beliefs – and the state standards and district policies components of the activity system's rules (contradiction C in Figure 10). In reference to classrooms where instruction was strictly standards-driven, Marybeth stated:

> When the standard's taught, they move on. There's not depth there. It's missing a lot of depth, and I just disagree that that is the way we should be doing education. To just let the standards drive what the teachers do in the classroom…Because we've got standards, we've got testing, and then we do testing on top of testing, right? It eats so much time… (1st interview, February 2018)

Marybeth then explained how this emphasis on state standards and testing diminished opportunities to differentiate instruction by student interest, such as assigning research-based projects for students to explore topics that they found personally meaningful or interesting. If students had spare class time, they were expected to utilize one of the test preparation resources to practice for the state-mandated end of course exam.

Case 7 Summary: Coherences and Contractions

In this case, the subject in the activity system was Marybeth. She engaged in the activity of teaching Biology, motivated by the objects of preparing students for future science courses and facilitating student learning and engagement with the content. Multiple tools were identified as Marybeth pursued these objects, such as her pedagogy, beliefs as a teacher, assessments, and educational technology.

Marybeth's colleagues and students formed the community of this activity system, each taking on different roles and responsibilities. Students were expected to take ownership of their own learning, while Marybeth acted as more of a facilitator in the classroom. Marybeth collaborated with her colleagues, developing cross-curricular projects and sharing websites and strategies for improving student learning and integrating education technology into the classroom.

The rules included Marybeth's own goals and expectations, as well as the state standards and policies at the school and district level. The outcomes identified in this case were student learning and growth, as measured by the end of course exam and various assessments throughout the year, and student engagement and enjoyment during class.

Various tensions were caused by contradictions within and between these activity system components. These contradictions included the dual nature of the educational technology as having both academic and nonacademic functionalities, frustration caused by constantly evolving software policies, and incongruities between Marybeth's beliefs as a teacher and the emphasis placed on the state standards and standardized testing. The following cross-case analysis section compares Marybeth's activity system to the activity systems of the other six cases.

Cross-Case Analysis

This section examines the data across all seven cases to address the following research questions:

1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?
2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?
    a. What specific educational technologies do STEM teachers use to differentiate instruction in their courses?
    b. What are the affordances of such technologies for differentiation?
    c. What types of challenges do high school STEM teachers face when using educational technology for differentiation?

First, similarities and differences are highlighted as they were identified among the cases. After the summary of similarities and differences among the CHAT analysis triangles, the data is then presented to address each of the research questions above.

Cross-Case Findings: Summary of Similarities and Differences among CHAT Analysis Triangles

Several of the same CHAT components were identified in the activity systems of the multiple (and sometimes all seven) cases in this study, and this section describes those commonalities and identifies distinguishing factors in each case. First, I examined the activity system triangles of the seven cases for similarities and differences among the individual CHAT components. Next, I present the findings from the comparisons of all seven cases in the context of the research questions guiding this investigation.

Similarities and differences in objects. First, student learning or mastery of the curriculum was named as one of the objects, or teacher's goals and motivations, in six of the seven cases: Camille, Jemma, Simon, Austin, Libba, and Marybeth. Student engagement was also listed as a component of the goals or motivation for Simon, Libba, and Marybeth. Camille, Jemma, and Simon, interestingly all math teachers at Actin High School, were also motivated by the object of student motivation during their teaching activities. Preparation for students' futures was considered a goal by Camille, Simon, and Marybeth, while Camille and Syrus aimed to facilitate student collaboration.

There were also some unique objects identified within these cases' activity systems. Simon was the only teacher who described student enjoyment as one of the goals of his engagement in the activity of teaching mathematics, and Syrus was the only participant who named developing students' problem-solving skills as a motivation for their teaching practice. Austin described a goal of engagement in teaching his STEM courses as helping students earn college credit, whereas none of the other teachers specifically mentioned college credit as an object. The other aspects of each activity system, such as teacher beliefs and rules, may have influenced the teachers' objects, as these components are intertwined and affect the subjects' engagement in the activity of teaching.

Similarities and differences in tools. All participants employed assessments, classroom management strategies, pedagogies, and beliefs as teachers; however, specific elements of these beliefs and pedagogical strategies varied for each case. Austin focused on building positive, collaborative relationships with and among his students. Camille, on the other hand, focused on helping students draw meaningful, real-world connections with the content. All teachers also integrated some aspects of differentiated instruction and grouping into their teaching practice.

Educational technology was identified as a tool in all seven cases, although the specific forms of hardware and software varied for each teacher and each subject. Student use of laptops was observed in all seven classrooms, although the laptops were different for each school system. Myosin City Schools used Dell laptops, while Actin City Schools chose Chromebooks. Marybeth, Libba, and Austin, all teachers at Myosin Junior High School, utilized the Canvas software in their classes. Google Classroom was identified as a common tool within the activity systems of Syrus, Jemma, Simon, and Camille, who were all employed by Actin City Schools. Additionally, Jemma, Simon, and Camille made use of the online textbook and EdPuzzle.com as part of the flipped classroom method in their mathematics classes. Both Syrus and Austin had STEM-specific software and hardware, such as SolidWorks, Inventor, and 3D printers, that were unique to their activity system triangles.

Professional development aided some of the subjects during the engagement in their teaching activities. The teachers in this study that specified the utility of professional development as a tool included Camille, Jemma, Syrus, Austin, and Libba. While budgets were considered among the rules of some of the activity systems, funding was also positioned as a tool in Syrus's activity system. As previously mentioned, Syrus had applied for grants and used that money as a tool to purchase other resources for his classroom.

Similarities and differences in community and division of labor. Similarities were also found within the communities of each activity system. Every activity system community included students, while some of the communities also included colleagues, administrators, and parents. Austin's activity system was the only one that included the technology coordinator and support staff, as this involvement was observed during one of the classroom observations (2nd observation, March 2018). Although the subjects or participants of the activity systems of the remaining six cases may have potentially had some interactions with technology coordinators or support staff, this component of the community and division of labor was not included as part of the CHAT analysis as it was not directly observed or discussed in an interview session.

The students' roles and responsibilities within each system's division of labor presented both similarities and differences among the cases. The greatest commonalities included students' responsibilities to interact and collaborate with peers, as seen in Camille's, Jemma's, Simon's, Syrus's, and Austin's activity systems, and students' role as being active and engaged, as described by Camille, Jemma, Syrus, Austin, and Libba. Camille, Simon, and Libba also expected students to provide input and feedback regarding their progress and understanding in class, which these teachers then used to form subsequent instructional decisions. Three teachers – Jemma, Syrus, and Marybeth – described the students' responsibility of taking ownership or responsibility for their own learning.

There were also some unique roles and responsibilities that were only found in single activity systems. One teacher, Simon, explained that the students were expected to take on the role as both the teacher and the learner during his class. Jemma was the only teacher who specifically said that sometimes her students took on a more passive role during some of the learning activities, such as watching the videos as previously discussed in Case 2.

Every teacher viewed their own role in the classroom as the "facilitator" or "guide" for student learning, with the exception of Camille. Camille explained that her role involved bridging the gap between students' efforts and their understanding, and, although there may be a facilitative nature to her statements regarding her role, she was the only subject who did not specifically use the word "facilitator" or "guide." Libba, on the other hand, was the only teacher that referred to her role as sometimes the lead for everything in the class, depending on the makeup of the class and the initiative of the students themselves.

Collaboration with colleagues was identified by multiple participants, including Camille, Jemma, Simon, Syrus, and Marybeth. Administrators were described as having roles and responsibilities related to encouragement and support by Jemma, Syrus, Austin, and Libba. Only two participants – Camille and Syrus – included the parents in their communities and divisions of labor, commenting on the parents' responsibilities to support and be involved in their child's learning.

Similarities and differences in rules. The rules component of the activity systems of all seven cases included teacher-generated goals and expectations, curriculum/state standards, and policies and guidelines as the school and district levels. The teacher-generated goals and expectations varied from teacher to teacher, as a result of the influence of other factors in each teacher's activity system, such as their beliefs as a teacher, their pedagogy, the object(s), and maybe even other rules. The specific curriculum or state standards differed depending on which courses each participant was teaching, and the school- and district-level policies and guidelines also varied between the different schools and even the different departments within each school.

Budgets were only identified specifically as rules in Syrus's activity system, although Libba also discussed how there were district-level policies about only using software that was free or that had already been purchased by the school system. In another variation between the cases in this study, only Camille and Jemma discussed the online format of the state's test as influencing and guiding some of their instructional decisions.

Similarities and differences in outcomes. As with the other CHAT components, some of the activity systems in this study shared similar outcomes. Every case included improved student learning for some students as an outcome of the participant's engagement in the activity of teaching. Both Jemma and Syrus described improvements in student accountability, and Marybeth and Jemma discussed improved student achievement as a result of their activities. Jemma and Libba communicated outcomes related to maximization of class time and increased efficiency as their classes moved through their respective curricula.

Distinct outcomes were also identified for some of the cases' activity systems. For example, the CHAT analysis of Simon's case, particularly based on interview data, revealed student motivation and development of new perspectives on content as outcomes of the activity. Austin was the only participant that specified college credit for some students, growth in student interest and enrollment in his school's STEM program, and teacher satisfaction and growth as results of engagement in the activity of STEM teaching. As results in his particular activity system, Syrus described student ownership of learning, positive student attitudes, improvements in students' problem-solving abilities, and more rounded learning experiences.

The outcomes for each case were the results or consequences of each participant's engagement in the activity of teaching their particular subject. Some of these outcomes were more generally related to the overall teaching activity, while others were more closely tied to the use of educational technology for differentiated instruction in high school STEM classrooms. In the following section, the findings of these cases are further analyzed and used to address each research question guiding this study.

Cross-Case Findings of Research Question One

This section investigates the following research question:

1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?

This research question is explored using the data from the classroom observations and interview sessions, which was also employed in the within-case analyses earlier in this chapter. Each within-case analysis was situated within the framework of Cultural-Historical Activity Theory; once analyzed within the context of CHAT, this allowed me to shift my focus to the specific tools of educational technology and differentiated instruction, as well as the merging of the two, and how they were viewed by each teacher.

All seven high school STEM teachers in this study were observed using educational technology to differentiate instruction in various ways. Their beliefs related to this topic were specifically explored during the interview sessions, as the teachers could use their own words to convey their views and thoughts on the use of educational technology for differentiation purposes in the classroom.

All participants in this study expressed their beliefs related to the utility of educational technology in differentiating instruction. Camille spoke positively about the use of educational technology to facilitate differentiation in her classroom, stating, "I definitely feel like [educational technology] has given me an option to differentiate more" (1st interview, January 2018). When asked to describe her general perspective or views on using educational technology to differentiated instruction, Camille said, "In the recent years, I found it very helpful compared to when I didn't have those same technological resources" (2nd interview, March 2018). Libba commented, "I think it's helpful…to help distinguish between who really knows something and who doesn't and to help them learn how to look at where they're actually at in terms of their learning" (2nd interview, March 2018). Marybeth also spoke in favor of using technology to meet the needs of individual students, explaining that it allowed some of her gifted students to individually dig deeper into the content while still participating and adding to the conversation with the rest of the class (2nd interview, March 2018).

Austin expressed his belief that the use of educational technology to differentiate instruction was "advantageous to student learning" for multiple reasons, including pacing, access to resources, and visualization (2nd interview, March 2018). Similarly, Syrus presented his beliefs related to educational technology related to differentiation, stating:

> I think it's certainly beneficial. I've mentioned some things that make my life and the kids' lives easier. I recall as a student myself, once you'd had a lecture and you moved on, that's it. If you didn't get it or if you didn't take notes, if you can't find the right book, if it's even in there, you're out in the cold, if you can't find somebody else who had it. I think technology allows us to keep things at the fingertips, and it's almost to the point where it's not really about what you know; it's about whether you know how to find out information. So, in that aspect, it's certainly useful. (2nd interview, March 2018)

Jemma also communicated her views that educational technology "helped tremendously" in differentiating instruction because students did not have to wait on her to move on through the curriculum and could work with the content at the speed most appropriate for them (1st interview, January 2018). Jemma went on to say that, although educational was a great tool for differentiating instruction, she believed that it did not eliminate the need for teachers in the classroom; even with the flipped classroom model allowing students to come in with some foundational knowledge, students still had questions and needed various amounts of guidance as they worked to build solid understanding of mathematics concepts (2nd interview, March 2018).

During the final interview sessions, the participants were also asked to comment on what could help them better use educational technology to differentiate instruction. In one example of a teacher's wishes for future technological affordances related to differentiation, Camille communicated:

> I don't know if technology would ever be able to do this, but a lot of times I think kids have trouble interpreting what a question is asking, so if it could ask it in a different way, the same concept…I think that would be a helpful tool for students that are just having trouble because, a lot of times, they know how to answer it, they just don't understand what the question is asking. (3rd interview, May 2018)

Jemma expressed her desire for educational technology to make it easier to create more individualized assignments for students. She stated:

> I need to be able to go in and set quickly, maybe I want this one to reach this percent efficiency and that one that. Or I can make a whole assignment, but then I can pull out different ones for different kids without having to make a new assignment, because that's really annoying…you have to remake a new assignment, and that makes it a lot more time-consuming and difficult to do, whereas if you can just say, okay, for this kid, do this assignment but pull out these questions, just focus on this. That would be my ideal, make it easy to quickly change for different students. (3rd interview, May 2018)

Based on the observations and interviews in this study, educational technology seemed to allow teachers to individualize certain learning activities more easily than traditional pencil-and-paper activities, but some assignments may be more time-consuming or difficult for teachers to personalize, even with current available technology.

Austin seemed optimistic about the potential of educational technology for differentiation in the classroom, commenting:

> I think a lot of the way that students are exposed to material is just through watching videos and seeing pictures, so I think the more support and tutorials that keep coming out over new hardware and software…as we continue to build curriculum more, and more support videos have been coming out by highly effective educators. It's really awesome to be able to use that to help differentiate, especially when you have so many students in the classroom with so many individual needs. In this type of environment, it's really hard. I can't be over everyone's should at once. I can't be over everyone's shoulder at once helping them with their specific individual and quite widely ranging problems. (3rd interview, May 2018)

As educational technology continues to evolve, these teachers may be able to apply new technologies and strategies to further improve the differentiated instruction in their classrooms. The next section examines the second research question, which is related to the participants' actual use of educational technology for differentiation purposes.

Cross-Case Findings of Research Question Two

In this section, I discuss the cross-case findings as I examine the data through the lens of the following research question:

2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?
    a. What specific educational technologies do STEM teachers use to differentiate instruction in their courses?
    b. What are the affordances of such technologies for differentiation?
    c. What types of challenges do high school STEM teachers face when using educational technology for differentiation?

Even though the participants taught various subjects and utilized different types of educational technology, there were some consistencies among some of the technologies used and the affordances of these technologies. The forms of educational technology and their affordances are discussed in the following section. The challenges identified during the teachers' use of educational technology to differentiate instruction are also discussed below.

Educational technology and differentiation: Student interests and choice. Differentiated instruction involves meeting students' individual needs by allowing them a certain degree of choice in their learning and appealing to their unique interests. Educational technology allowed Austin to provide students with some autonomy and choice, which contributed to the differentiated instruction in his STEM classroom. Additionally, educational technology provided Austin's students to explore their own interests. During an observation in Austin's classroom, students were all working on a project and were expected to meet certain criteria; however, every student's design was slightly different and they were given the freedom to decide what their product would look like and which actions it could perform (1st observation, February 2018). In another example of educational technology affording student choice and integrating students' interests, Austin explained:

> When we had our robots built, I had three tasks they all had to do, but then I had two tasks that they got to do and create the outcomes for that task on their own...they have the autonomy to create a lot of their own ideas and projects and rubrics…and we use Canvas as our learning management system, which has a really nice rubric feature. (1st interview, February 2018)

In this example, Austin allowed students to infuse their own interests into their projects and have input and choice with their learning activities.

Libba also provided students with opportunities to explore their own interests and choose certain aspects of activities that appealed to them. She described a project where students could create either a tangible or digital product to show how genetically modified organisms were made (1st interview, February 2018). Students got to choose the genetically modified organism, as well as the mode in which they demonstrated their understanding of the concept of genetic modification. Libba sometimes gave students options when reviewing content at the end of a chapter, such as creating a hand-drawn poster or a digital PowerPoint or Prezi presentation. In both of these instances, the educational technology provided more options for students to work with and display their knowledge of the content.

Marybeth, also Biology teacher at Myosin Junior High School, described an example where technology appealed to student interests and provided them with a choice during instructional activities. In this specific example, an online simulation modeled ecosystems, and students could choose which ecosystem they wanted to track and investigate. Marybeth elaborated, "A kid who [may not] care about the desert but [may] think polar ecosystems are really cool…it helps kids to grab onto more content because the Internet's so diverse…I think you can always find something to help keep kids engaged" (2nd interview, March 2018). According to Marybeth, student engagement was improved during this exercise by giving students a choice and letting them research topics that piqued their own interests.

Educational technology and differentiation: Content access and delivery. Educational technology can facilitate meeting students' individual needs by providing students with multiple ways to access and work with content. Austin mentioned using a wide range of software and resources, such as PowerPoint, Canvas, Nearpod, and video tutorials, to reach all of the students in his classroom (1st interview, February 2018). Austin also utilized various strategies, including direct instruction and project-based learning, to suit the various learning styles of his students. Austin described the value of technology in the visualization of content, saying, "Trying to explain something to someone versus showing it to them and explaining it has two complete different results a lot of the time…in terms of visualization, the technology is great" (2nd interview, March 2018).

Marybeth named Google Translate as one of the technological tools that improved the accessibility of content in her classroom. She stated, "It certainly helps with my kids that are not native English speakers that they can use Google Translate…they can pick stuff up that they need to know in their native language if they can't get it in English" (2nd interview, March 2018). In this instance, educational technology served as a tool that facilitated differentiated instruction for students from diverse backgrounds.

Camille, Simon, and Jemma all employed the flipped classroom model in their mathematics classrooms. Educational technology was essential to the successful implementation of this model, as the content was delivered to students using video lessons on EdPuzzle.com. Camille explained:

> [Students] have the ability to just watch and take it in and then take notes, instead of having to do that simultaneously because, traditionally, kids are going to take notes in the class and may just be writing down what's on the board and not actively thinking about what's happening. (1st interview, January 2018)

The educational technology that facilitated the flipped classroom model increased the accessibility of the content, as students could watch these video lessons as many times as they wanted and from anywhere as long as they had a device and internet access. Camille also commented that the educational technology and flipped classroom model helps keep students on track when they were absent from school, stating, "They can stay current with the content and kind of keep with where we are in the class" (2nd interview, March 2018).

Libba also utilized educational technology to improve the accessibility of content to meet the needs of the students in her classroom. She named multiple digital resources, such as the Canvas learning management system, WebQuests, Virtual Labs, and videos, that allowed her to provide options for students to access and work with the concepts outlined in the Biology curriculum. In commenting on the affordances of these educational technologies, Libba said, "A student who maybe learns in a different form would have lots of different options in terms of either hearing or seeing or manipulating something through the computer. It makes it easier to do those things" (2nd interview, March 2018).

Certain software, such as Google Classroom, increased the accessibility of content in Syrus's STEM courses. He explained:

> Whatever we do in the classroom, I tend to allow the kids to have access to anywhere. If it's the Google Classroom, for example, that if I've got a rubric, I've got a checklist or an assignment sheet or video, whatever it is, even if we've done it in the classroom, I will say, "Well, here's your resources for this particular project, and if you're absent you've got no reason that you could not have come across some internet access through your phone, computer, or come in before school." It kind of eliminates a lot of showing up two days after you're absent and going, "What did I miss?" It saves me that – and the stress of that kid trying to catch up. If they really want to stay up, they can do that. (2nd interview, March 2018)

Syrus used this educational technology to make the content available to students even outside the classroom and to provide the students with a variety of resources to help them reach their learning goals. This contributed to differentiated instruction as students who learn at different speeds and in different ways were given options in how to access the content to best meet their needs.

Educational technology and differentiation: Assessments and immediate feedback. In order to meet individual students' needs and ensure that learning opportunities were maximized, the teachers employed formative and summative assessments. Austin used technology for both formative and summative assessments; he also described the use of well-designed rubrics, which were created and made available to students using educational technology, to guide students' performance-based assessments. For Austin's STEM courses, "both the formative and summative assessments are usually work products," and, due to the nature of the class content, these assessments were dependent on students' use of technology (1st interview, February 2018).

In another example of the use of educational technology to aid in differentiated instruction, Libba and Marybeth both used the online Kahoot and Quizzizz games to formatively assess student learning. Libba explained that these games helped students "figure out what they know and what they don't know," as well as helped her gauge how the class as a whole was grasping the content (1st interview, February 2018). Libba also used another website, Socrative.com, to deliver quizzes and formally assess students' understanding and determine when the class could move on to new content. When asked how she had used technology to differentiate instruction in the classroom, Libba responded:

> If we have an exit ticket or do a digital assessment in some form, like a Quizzizz or Kahoot or something, and students make a particular score, from that point they can branch out and do different assignments based on whatever grade they earned on that. It

> may be an online assignment, may be a paper assignment, it may be different. But at least, that way it gives you a quick sense of feedback in terms of where they stand. (2nd interview, March 2018)

The assessments delivered through Kahoot, Quizzizz, and Socrative all provided immediate feedback to both the students and the teacher. Marybeth commented on the importance of consistent assessment, saying, "Sometimes I open class with formative assessment, with a Quizzizz; sometimes I end class with a Quizzizz. But that formative assessment piece is really pretty much always there" (1st interview, February 2018).

The information gained from these formal and informal assessments was used to inform instructional decisions as Marybeth and Libba moved through the curriculum of their Biology courses, contributing to the differentiated instruction and meeting of students' individual learning needs. Marybeth stated:

> With Quizzizz, I can really see who in my class is slow to pick up the concept and who's really got it. That allows me sometimes to take my kids that have grasped onto something and maybe work or peer tutor with another kid that maybe is a little bit slower. I think that kind of helps everybody involved. (2nd interview, March 2018)

Marybeth also used EdPuzzle.com to assign videos and ask questions as another way to deliver formative assessment. According to Marybeth, this software is "diagnostic," allowing the teacher to see which students missed certain questions (2nd interview, March 2018).

Syrus used Google Forms to deliver quick formatives assessments in his STEM classroom. He explained:

> We'll look at the data as far as a quick way to review what the class is thinking about something. You can chart that up and discuss in a hurry what the class is missing as a

whole…that allows me to have some concrete data on whether they were successful at learning all of the required objectives for the particular unit. (3rd interview, May 2018)

Syrus then used this data to adjust subsequent instruction, activities, and assignments, providing differentiation as students progressed in their learning.

Camille, Simon, and Jemma utilized mathematics-specific software for formative assessment in their courses, including IXL and the online textbook software. Simon valued the information he could gain about students' understanding based on the data from these educational technologies. He explained:

> I can look specifically at what questions students are missing or struggling with and are not doing altogether and know whether or not what specific content or concepts they might be struggling with…I can see very quickly how much of the basic concept students have acquired and whether or not they have it. (1st interview, January 2018)

In addition to providing formative assessment data to the teacher, Camille described how integrating the online textbook resource and IXL software into the class routine benefited her students, stating:

> They get immediate feedback. That's one of the biggest benefits I see to the technology. Differentiation is that they can get immediate feedback on what they're doing as opposed to working out a whole set of problems on paper and then waiting for me to tell them if they're right or wrong. (2nd interview, March 2018)

According to these Actin High School math teachers, both of these digital resources also improved differentiated instruction by individualizing pacing, as described in greater detail below.

Educational technology and differentiation: Pacing and individualized assignments. Another component of meeting the diverse needs of students in the classroom involves acknowledging that students come into the classroom with different ability levels and learn at different paces and then working to adjust instruction to provide every student with the opportunity to improve and be successful. Austin communicated, "Everyone's going to learn at different rates. Some people get it faster than others. What I think technology affords is opportunity to engage in high quality and high level learning" (2nd interview, March 2018). By providing students with video tutorials and other online resources on Canvas, Austin's students could be somewhat independent and move at their own pace. Austin stated:

> It's great because students that are high fliers that really move fast can take control of their learning on their own without me having to go and give them that detailed help, but students that really struggle, they'll watch the video, and they might have to pause. They can rewind it. If they're English-language learners, they can put subtitles on their and read in their native language…for differentiation, it's perfect because they control their pace. (3rd interview, May 2018)

Educational technology afforded each student the opportunity to learn at the speed that was most comfortable for them, which contributed to the differentiation and meeting the needs of the diverse learners in the classroom.

Syrus, another STEM teacher, described how educational technology allowed his students to work within their zones of proximal development and differentiate instruction. He stated that the software utilized in his classroom "let [students] design things that best fit their skill set" (2nd interview, March 2018). He elaborated:

> For example, I have a student who transferred in who had never seen CAD, and this is the second year class for him and knowing that he didn't have that, him getting any kind of design done was going to be a feat in itself to strive to. And allowing him to work within his means but still push his knowledge base a little bit further along and some varying level of that for almost every kid. When you have special needs kids, whenever you have kids who have emotional issues where they're not going to be in class somedays, you kind of have to let them be able to work from home through Google Classroom resources – that kind of stuff. (2nd interview, March 2018)

Syrus acknowledged his students' unique differences and needs and employed the available educational technology to differentiate instruction to help each student reach their maximum potential.

Similarly, Camille described some of the affordances of using educational technology as part of the flipped classroom model, which involved creating video lessons with the Explain Everything iPad app and delivering the to students through EdPuzzle.com. During the interview sessions, Camille spoke about how the educational technology somewhat differentiated pacing for students, saying that students "can pause it if they need to; they can watch the whole thing and then go back and take notes if that helps them to focus on just watching…they can go back and rewatch it later when they're studying" (2nd interview, March 2018).

Regarding individualized assignments, Austin stated:

> With technology sometimes I'll have to abbreviate assignments for individuals…Some move at faster rates than others, so as long as I'm able to see skills, then I'm able to say, if we're making three parts, and I've got all my skills basically done in two, then I can have some of my slower students [be] done after two and differentiate that way as long as they

> can demonstrate the skills. It's a little bit harder for my faster students to differentiate, my top students…you don't want to punish them for finishing efficiently or fast, so it's usually incentive-based work or side projects that they can work on…I'll have more challenging tasks, and I'll usually tie extra credit or a 3D printing incentive…so they're motivated to get to do that. (2nd interview, March 2018)

In this case, educational technology allowed Austin to vary assignments to meet his students' individual learning needs based on their ability levels and the time required to complete instructional tasks.

Camille, Simon, and Jemma, all mathematics teachers at Actin High School, incorporated some of the same software which aided in differentiation during their everyday teaching practices. All three of these mathematics teachers used the online textbook resources and IXL software for students practice and formative assessment during class time, as part of the flipped classroom model. The affordances of the online textbook and IXL software for differentiation included immediate feedback and more individualized pacing for students. Camille explained:

> [The IXL software] gives students feedback in real time…and gives them instruction on how to correct some of the errors that they're making, so it lets kids move at their own pace, and it's responsive to what they put in so that if they aren't doing well, it's going to give them practice at the lower end. If they're doing well, it's going to push them to some higher level questions. (1st interview, January 2018)

According to Camille, this software provided students with quality feedback by giving them instruction on how to correct common mistakes they might have made, specifying "why they're making their mistakes instead of just being told [they're] wrong" (2nd interview, March 2018). Camille also stated:

> Usually by the end of each day, the student gains a level of confidence they can complete an assignment…they know that they're doing well. They know they have the content mastered, and they can prove that also by showing that they have been able to do this set of problems correctly. (1st interview, January 2018)

By knowing immediately if they were working problems correctly, students built confidence and could move on when they were ready. This software served as formative assessment and contributed to differentiation as students' individual needs could be better addressed. In addition to providing immediate feedback, Camille stated that the online practice "bridges the gap" and allows her more time to work individually with students on whatever they were struggling with (2nd interview, March 2018).

Simon described similar affordances of the educational technology in his classroom. He explained:

> In my classroom, the biggest thing I have done with technology using the Chromebooks is within the homework assignments that each student is given, based on the level of class that it is. They have to get a percentage of problems right in order to get full credit, so, in that, kids who do the initial problems, which are typically more basic, can get that percentage and get their credit, but kids who can exceed that have opportunities on that homework to do more problems that are more in-depth, higher order questioning type problems. They can do those and attempt them and see if they can get them right. (2nd interview, April 2018)

In addition to more individualized assignments, Simon described pacing as one of the affordances of the educational technologies utilized in his classroom. He stated:

> The pacing is probably the biggest thing because, with paper and pencil, in order for them to get that kind of feedback, they basically have to stay with me and I have to grade it, and I'm not afforded that luxury within a class period; whereas, doing it online with technology, they can get that immediate feedback and know, and it allows them to work ahead if they want to. (2nd interview, April 2018)

In these instances, students who had mastered content were allowed to move ahead to new or more challenging concepts, and students who needed additional practice or to work at a slower pace were also allowed to do so; this allowed Simon to better meet his students' individual learning needs.

Jemma also employed the online textbook resource to differentiate instruction. During one of the interview sessions, Jemma explained that she adjusted the number of attempts students had to correctly answer each practice problem based on their ability levels (1st interview, January 2018). Additionally, she had the ability to modify the minimum percentage mastery for each class or even each student.

Marybeth described individualized pacing and assignments as affordances of educational technology in relation to differentiated instruction in the classroom. She stated:

> Technology allows me to move at different paces with different kids. If they are watching videos and we flipped the classroom, it can be at their own pace, and my fast workers can go fast and my slow workers can slow down. They can watch the video multiple times. I think with digital, it also allows kids to be able to do homework at different paces…I can take work, and, if I need to really dial it down for a kid, I can do that and post it back into Canvas, and they've got access to it at night or whenever. (2nd interview, March 2018)

As demonstrated in the examples above, various forms of educational technology allowed these teachers to differentiate instruction in their classrooms in several different ways, including more individualized assignments and pacing. The challenges that teachers experienced during their engagement in the use of educational technology for differentiation purposes are discussed in the next section.

Challenges of using educational technology for differentiated instruction. While educational technology afforded the participants in this study many opportunities to better differentiate instruction in their classrooms, challenges were also observed as these teachers tried to integrate technology to meet the diverse needs of their students. The contradictions and tensions examined in the CHAT analysis of each case served as the lens to investigate these challenges related to the use of educational technology to differentiate instruction in STEM classrooms.

One common primary contradiction was identified in the dual nature of educational technology. This dual nature was explained in detail previously in the individual case analyses of six of the seven cases. Syrus was the only participant who did not mention this contradiction, and this contraction was not detected during the two observations of Syrus's classes. Camille, Jemma, Simon, Austin, Libba, and Marybeth, on the other hand, did experience the challenges associated with educational technology being used by the students for both their intended and unintended purposes. At times, the technology was utilized by the students to reach their academic goals. Other times, however, the technology was not used as it was intended; it could actually serve as a source of nonacademic entertainment or even a distraction, preventing students from progressing in their learning and meeting the teachers' objectives.

Contradictions were identified between the tools and the division of labor activity system components in both Camille's and Libba's cases. In contradiction A in Camille's case, some students did not buy into the flipped classroom model and failed to complete their assigned work. Libba described another secondary contradiction between the teacher's component of the division of labor and the available tools, which was represented in the activity system analysis as contradiction D in Figure 9. According to Libba, the time and effort required to integrate new technological tools in the classroom added to teachers' lists of responsibilities and could cause teachers to feel stressed and overwhelmed. While there are differences between the specific aspects of the division of labor and the details of the tools involved, both of these contradictions caused tensions as the members of the community (either the teacher or the student) were resisting certain responsibilities, hindering the participant's achievement of the object.

Similar contradictions were also found between the tools and the objects of several participants activity systems. In Libba's activity system, there were two contradictions between the technological tools and the objects. In contradiction B, the educational technology sometimes did not function properly, inhibiting use of these tools in the attainment of Libba's goals of student learning, productivity, and engagement; Simon also experienced the malfunctioning of educational technology in contradiction A of his activity system, which obstructed the achievement of the object. In contradiction E, Libba explained that the vast amount of digital resources the students were expected to use actually caused the students to feel overwhelmed, which also inhibited the achievement of the activity system object. Some of Marybeth's students, particularly students who were English language learners and new to the Myosin City Schools system, had difficulties with using the educational technology, shown by contradiction B in Figure 10. Comparably, in Austin's contradiction A, some of the students lacked basic computer skills that interfered with the use of educational technology to reach the activity system goals. In contradiction B, Austin found that sometimes the technology did not serve as the best tool to complete certain tasks. Syrus explained that he had to sort through and reject the forms of educational technologies that would not help him meet his goals in contradiction B.

Three contradictions between the rules and division of labor were identified in the activity systems of Jemma, Simon, and Libba. This conflict between teacher-generated goals and the students' responsibilities – one constituent of the division of labor – is represented as contradiction C in these teachers' activity system triangles (Figures 5, 6, and 9). In one instance, Jemma expected her students to engage and take responsibility for their own learning, but some of the students failed to meet this expectation. Similarly, Simon also had students who refused to do their work, which contradicted the goals and guidelines Simon generated as the teacher. Some of Libba's students did not participate in classroom activities, such as collaborative group work, or take on active roles in learning. In all three of these examples, the students' failure to perform their responsibilities within the activity system conflicted with teacher-generated goals for the class, causing tension that hindered the achievement of the objects of the teachers' activity systems.

Marybeth and Syrus both experienced contradictions between the rules and tools within their activity systems. In Marybeth's activity system triangle (Figure 10), contradiction C occurred when the state standards and district policies, which served as rules guiding this activity, conflicted with Marybeth's beliefs as a teacher, one of the activity system tools. According to Marybeth, the emphasis on state standards and testing prevented her from teaching the content in greater depth and allowing students to explore some of their own individual interests related to Biology. Syrus expressed two other contradictions between rules and tools.

The guidelines related to the budget sometimes conflicted with the cost of the educational technology tools that he wished to purchase (conflict A in Figure 7). Additionally, the school district's policy on software manipulation interfered with Syrus's ability to use the technological tools as he wanted or needed to (conflict C in Figure 7). The teachers at Actin City Schools did not have the authority or power to make certain changes to the software, which prevented or delayed some of Syrus's instructional activities.

There were also contradictions and tensions that were unique for some of the teacher participants in this study. Contradiction C in Syrus's activity system was the only quaternary contradiction specifically identified in this study. In this contradiction, components of some of the students' activity systems conflicted with the students' division of labor component of Syrus's activity system. In another unique contradiction, Jemma described the dual nature of professional development as a tool, when professional development sessions sometimes presented conflicting information and ideas (contradiction B in Figure 5). It is possible that the other participants in this study may have also experienced similar contradictions but did not acknowledge or focus on those particular matters; however, since the purpose of this study was to explore high school STEM teachers' perspectives and use of educational technology to differentiate instruction, the data was presented strictly as it was communicated by the teachers during the interviews and as it was perceived during the classroom observations.

This chapter detailed the within-case analyses of the seven teacher participants in this study and presented the cross-case findings from the comparison of all seven cases. The individual case analyses, viewed through the lens of CHAT, portrayed each teacher's engagement in the activity of teaching a STEM-related course. These activity systems also allowed for the analysis of the contradictions and tensions experienced during these activities and provided a means to focus in on each teacher's use of educational technology tools for differentiated instruction purposes. The cross-case analysis compared the findings from the individual cases, highlighting the similarities and differences between these cases. The cross-case analysis also framed the findings in the context of this study's research questions. Chapter 5 will discuss the implications of this study related to how high school STEM teachers can employ educational technology to differentiate instruction and potentially prepare for the challenges and contradictions that may coincide with these activities.

Chapter 5

Discussion, Implications, and Conclusions

Several studies have been conducted to investigate differentiated instruction at the elementary and middle school levels, but few studies specifically explore the use of educational technology to differentiate instruction at the high school level (Maeng, 2016; Maeng & Bell, 2015; Milman, Carlson-Bancroft, & Boogart, 2014; Robinson, Dailey, Hughes, & Cotabish, 2014; Wu, Kuo, & Wang, 2017). The purpose of this qualitative study is to investigate if and how high school STEM teachers use educational technology to differentiate instruction in the classroom in order to meet the diverse learning needs of their students. Additionally, this study aimed to examine the perspectives of teachers of high school STEM-related courses related to the use of educational technology for differentiation purposes. A multi-case study approach was used to address the following research questions:

1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?
2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?
    a. What specific educational technologies do STEM teachers use to differentiate instruction in their courses?
    b. What are the affordances of such technologies for differentiation?
    c. What types of challenges do high school STEM teachers face when using educational technology for differentiation?

This qualitative study involved conducting interviews and classroom observations for seven high school STEM teachers from two different schools that were implementing one-to-one technology initiatives: Actin High School and Myosin Junior High School. Three semi-structured interviews and two classroom observations were conducted for each of the teacher participants. The data obtained from these methods was first analyzed through the lens of CHAT in order to situate the components of each activity system and identify tensions and contradictions within each system. Next, the focus was shifted specifically to the use of educational technology to differentiate instruction in order to address the research questions above.

Discussion

Although few studies have been conducted to specifically investigate the use of educational technology for differentiated instruction purposes at the high school level, the findings of this research indicate that the high school STEM teachers in this study were employing educational technology for the purposes of differentiation to meet the needs of diverse learners in the classroom. A variety of educational technologies were observed in the STEM-related classrooms of the seven participants in this study, including many forms of both hardware and software. The details of these findings were presented in Chapter 4. An overview and discussion of these findings is presented below.

Affordances and Benefits of Using Educational Technology for Differentiation

As previously discussed during the cross-case CHAT analyses, there were numerous similarities and differences among the CHAT components making up the activity systems of the participants in this study. Despite the varied educational tools that were used (e.g., the software programs and devices), several common strategies, affordances, and benefits were identified in relation to the use of educational technology for differentiation, even among teachers of different subjects. Although the participants were from two different school systems that were at two different points in the one-to-one technology initiative implementation, there were similarities among the classroom activities observed and the teachers' communicated experiences and perspectives. These similarities are discussed below.

Pacing. According to Altemueller and Lindquist (2017), technology has the potential to personalize instruction, but "we also need to focus on the individual needs of students and consider the rates at which they acquire information and knowledge" (p. 344). Teachers' ability to use technology for pacing instruction to achieve their goals for student learning has also been discussed by Wilson (2011). Wilson (2011) states that technology facilitates pacing in the classroom, helping teachers work through the curriculum more quickly and allowing students to develop higher understanding and to experience more in-depth learning. Based on the findings of this study, one of the most prevalent affordances of educational technology for differentiating instruction was pacing. Although the participants' goals somewhat varied, pacing contributed to the participants' efforts in trying to reach the objects of their activity system, including student learning and mastery of content.

In this study, multiple activities were observed or discussed during interviews that involved educational technology allowing students to move as slowly or as quickly as needed. Jemma, Camille, and Simon incorporated the flipped classroom model, which was dependent on the use of various forms of educational technology. With these technologies, students could rewind, pause, or rewatch the videos if they were struggling with certain concepts or needed to review the content. Students could also move ahead to more challenging content if they were ready. Teachers were also able to spend more time interacting with students who were struggling with the material. This met the needs of students at different ability levels and learning speeds, as well as allowed the teachers to appeal to students' different learning speeds and styles.

Accessibility of content. A second common affordance of educational technology for differentiated instruction was the increased accessibility of content and more individualized assignments. As discussed by Zheng (2014), increased use of technology in the classroom "transformed student learning in a more individualized and differentiated direction" (p.599). In the current study, online resources and videos allowed students to apply subtitles, which was appealing to English language learner students. Additionally, students could view and work with content in different forms as provided by the teachers through online learning management software, such as Google Classroom and Canvas. The educational technology observed and discussed in this study also extended learning opportunities past the time and location restraints of the classroom. Students were able to access content on mobile devices and their computers at home outside of school hours or if they were absent.

Autonomy and choice. Educational technology also provided teachers with more opportunities to offer student choice and integration of students' personal interests. For instance, technology-based projects in Austin's and Syrus's classes allowed students to practice the same essential skills while creating unique products that appealed to their own interests. In some of the cases of this study, teachers let students choose from a variety of formats for demonstrating their knowledge, mastery of skills, and understanding of the content in the course; the educational technology provided access to the digital components needed for several of these formats. This aspect of differentiated instruction – increased autonomy and choice – was similar to the findings in the study by Maeng and Bell (2015), where the teacher allowed students to choose from multiple options with which they were most comfortable working with the content, such as reading about the content, researching the content online, or participating in teacher-guided instruction.

Assessments and feedback. Assessment is a vital component of differentiated instruction (Doubet, 2015), and educational technology can be used to facilitate the administration of assessments and to provide quality, timely feedback to both teachers and students (Kaur et al., 2017; Maeng, 2016). In this study, efficient delivery of assessments, ability to assess students' learning in various formats, and immediate feedback were also named as some of the affordances of educational technology for differentiated. In order to adjust instruction to meet students' learning needs, the teachers utilized assessments to determine student mastery and understanding. In multiple cases in this study, formative assessments, and sometimes summative assessments, were more easily delivered using various educational technologies, such as the mathematics online textbook and IXL software in Jemma's, Camille's, and Simon's cases, or the Kahoot and Quizzizz software in Libba and Marybeth's cases. The educational technology provided teachers with a wider range of choices to deliver assessments in order to measure students' mastery of content and skills. In addition to the teacher gaining valuable assessment data, the immediate feedback provided by these educational technologies also allowed students to self-assess, enhancing students' accountability and ownership of their learning.

Challenges of Using Educational Technology for Differentiation

Both the integration of educational technology in the classroom and implementation of differentiated instructions carry with them numerous challenges. With differentiated instruction, teachers have experienced conflicts related to time constraints, limited access to resources and instructional materials, their own beliefs about technology, and the cultivation of pedagogical knowledge and skills (Basham et al., 2010; Maeng, 2016; Maeng & Bell, 2015; Mastropieri et al., 2006; Robinson et al., 2014; Stetson et al., 2017). Studies have also shown that the integration of technology presents challenges as well, including availability of resources, teacher comfort level with technology integration, teacher beliefs about technology, administrative support, and disparities between students' skills and experiences with using technology (Batane & Ngwako, 2017; S. Howard & Gigliotti, 2016; Prensky, 2001). In addition to the benefits and affordances of educational technology for the purposes of differentiation, the participants in this study also experienced challenges and obstacles during their engagement in the activity of teaching a STEM-related course. This study focused on the challenges and obstacles related to the use of educational technology to differentiate instruction in the classroom. Using CHAT as a theoretical framework, these challenges and obstacles were analyzed as contradictions between the components of the participants' activity systems.

Technology as a distraction. Various studies have described students' use of technology for nonacademic purposes, which can detract from student learning (Boardman, 2012; Cho & Littenberg-Tobias, 2016; Lei & Zhao, 2008; Storz & Hoffman, 2013). The most prevalent challenge in the current study was students' misuse of the educational technology in the classroom as a result of the primary contradiction or dual nature of the educational technology. Six of the seven cases in this study reported this an issue or obstacle in obtaining the goals of the classroom activities. Sometimes, the technologies were used academically as they were intended by the teacher; however, sometimes the technology became a distraction or was even sometimes used for cheating purposes. When students misused the educational technology, their learning was impeded. For example, when the technology became more of a distraction than an academic tool, students did not complete their required tasks and did not engage with the course content as needed to reach the teachers' learning and performance goals for those students. When students used the technology to cheat, students' understanding and mastery was misrepresented and, again, their learning goals were not achieved.

Negative attitudes toward technology. Previous studies have explored teachers' and students' attitudes toward the use of educational technology in the classroom (Cho & Littenberg-Tobias, 2016; Incantalupo, Treagust, & Koul, 2014; Qing, 2007). Based on the findings of the current study, some participants experienced challenges related to students' and even some teachers' refusal or reluctance to adopt and use educational technology. In Camille's case, she explained that some students just did not buy into the flipped classroom model and did not perform their responsibilities as active learners. The flipped classroom model was a pedagogical tool that incorporated several different educational technologies and placed more responsibility for learning on the students and demanded the students' active participation. Some of the students resisted this responsibility as they may have expected to passively receive information from the teacher through lecture and more direct instruction. Certain students' refusal of their responsibilities as part of the division of labor caused tension and instability within Camille's activity system and negatively affected Camille's ability to attain the object. Libba, who did not employ the flipped classroom model, also experienced students who chose not to perform the assigned tasks, although this was described for both technology-related and paper-and-pencil assignments.

Reliability and demands of technology integration. Tensions were also discovered that resulted in some teachers and students feeling overwhelmed or frustrated by the integration of new educational technology in the classroom. In multiple examples described previously in this study, the educational technology did not always function properly, similar to the findings of other studies related to technology use in the classroom (Allsopp, McHatton, & Cranston-Gingras, 2009; Boardman, 2012). This occurred both with software programs, as some websites were found to be temporarily unavailable, and with hardware, like when the laptops did not operate as expected to perform necessary tasks. Some of the participants in this study also communicated that teachers felt overwhelmed by the vast amount of technology available and the time and effort required to learn how to appropriately implement those technologies in the classroom. Similarly, the teachers communicated that students could be overwhelmed by the amount of technology they were expected to use on a daily basis.

Implications

The findings of this study have implications for teachers and administrators that recognize the importance of meeting the needs of the increasingly diverse student populations in our schools and are working to integrate educational technology for the maximum benefit of these students. These implications may be particularly valuable in schools that are implementing a one-to-one technology initiative, as this enhances the accessibility of educational technology for both students and teachers.

This study provides context and specific accounts from the perspectives of high school STEM teachers as they worked to integrate technology and meet the learning needs of their students. The insight gained from this research may help other teachers, administrators, and support staff as they incorporate educational technology in the classroom and work toward similar goals of improving student learning and student engagement. By identifying the affordances and potential challenges of the educational technologies in this study, other teachers may be able to anticipate similar situations and work to prepare for some of the common obstacles and difficulties. For example, if teachers expect that there may be some students who lack foundational computer skills or that there may be technological connectivity issues, they may wish to allot time to work on these foundational skills during their lessons or prepare alternate backup assignments in the case that a technology-dependent activity does not go as planned. If teachers approach the integration of new technologies calmly and with a plan, then they may be able to avoid feelings of frustration and being overwhelmed by the vast amount of digital resources, as communicated by some of the teachers in this study. Moreover, this work offers practitioners and researchers in the field a language that can be used in planning, researching, and teaching differentiated instruction with educational technology.

There are several positive takeaways from this study that may be applied as teachers and administrators prepare for the integration of educational technology to differentiate instruction in the classroom. The participants in this study communicated that they benefited from collaborating with colleagues about the strategies and technologies, both software and hardware, that they used in the classroom which facilitated differentiated instruction. Administrators may wish to designate times and training during professional development or in-service days to allow teachers to work together and explore new educational technologies.

Teachers and administrators may also find value in understanding the affordances and constraints of the educational technologies utilized by the participants in this study as they selected and utilized hardware and software in the classroom. For instance, some software may allow students to exert greater control over their own pacing or may allow teachers to individualize assignments. On the other hand, the technology also has the potential to distract students or facilitate academic dishonesty. As the number of technological resources available continues to increase, those who work in education could benefit by realizing the possibilities and potential of educational technology to differentiate instruction and applying this knowledge to maximize student learning.

Reflections

During the data collection and analysis process, some findings struck me as particularly surprising or interesting. It is important to note that, in addition to taking on the role of the researcher in this study, I am also a high school STEM educator myself and have had my own personal experiences with integrating educational technology and differentiating instruction in the classroom.

As I was conducting the interviews and asking the participants questions related to educational technology, differentiated instruction, and the intersection of the two, I noticed that some teachers were hesitant to actually label their instruction as "differentiated." For example, Libba communicated that her instruction was not really differentiated because she did not have a different assignment for each student. Upon examination of the instructional activities and Libba's interview responses, however, Libba was indeed differentiating instruction to meet students' needs in several different ways. With the help of educational technology, she presented content in multiple forms, allowed students to manipulate and work with the content in various ways, delivered assessments that provided immediate feedback, and adjusted her instruction based on the assessment data. She also sometimes used this data to determine grouping and somewhat individualize the assignments for certain groups or students. All of these strategies lie at the heart of differentiating instruction – Libba was making instructional decisions to meet the diverse learning needs of the students in her classroom.

During the interviews, other teachers also expressed reluctance in naming their instructional strategies as differentiated, although they did seem to instinctively be adjusting instruction to meet the needs of the students in their classrooms. I also noted that, although the use of educational technology to differentiate instruction was not necessarily one of the participants' explicit or intentional goals, it was indeed observed as though it had permeated the teachers' routine engagement in the activities of teaching STEM-related courses as they worked toward their respective goals, such as student learning and engagement. Although the focus of this study was the use of educational technology for purposes of differentiation, this did not seem to be as much of a conscious decision on the teachers' part as it was an intuitive, natural culmination of effective teaching practices that included differentiation. Educational technology was used as a tool that, when applied appropriately, could significantly facilitate differentiated instruction, which, in turn, could facilitate student learning.

During the activity system analyses, some teachers did not mention certain components that I had originally anticipated. For example, some teachers did not mention administrators, parents, or technology coordinators as members of their communities or as having a role in the division of labor of the activity. This does not necessarily mean that these components did not actually exist or interact with the participants; it could be that, for various reasons, the participant chose to focus on the particular members of the community who they had the greatest amount of contact with or who they felt had the greatest influence on their engagement in the activity.

It was not surprising that each case had some unique features. No two teachers, students, or classes are exactly the same. There were, however, several shared features and commonalities identified during the cross-case analysis, such as the affordances of educational technology and the challenges encountered during engagement in the teaching activities. These commonalities demonstrate how the selected high school STEM teachers are currently using educational technology for differentiation purposes. Some of these findings could potentially translate into useful strategies for other teachers as well.

Throughout this research process, I reflected about what I learned as a researcher, including what I felt went well and what I would change in the future. In forming research questions, I originally attempted to cover too many topics and had to narrow the scope of the research questions as the study progressed. I also felt reluctant to revise my research questions during the process, and, in the future, I plan to be more open and flexible in adapting the research questions and interview questions to meet the needs of the study as it unfolds. The number of interviews and observations for each of the seven participants did provide a large amount of data, which contributed to the thick, rich descriptions of the cases; however, this amount of data was also overwhelming as I tried to navigate the analysis and writing processes. In the future, I hope to adjust the number of participants, interviews, and observations to better meet the time constraints of the study. Also related to time constraints, this study could have potentially benefitted from interview time being specifically allocated for review the activity system triangles with the participants. Although the interview data was sent to the participants to ensure that they felt it was an accurate representation of their perspectives, none of the participants responded with any revisions. It is possible that additional insight could have been gained from discussing the activity system triangles with each participant during the final face-to-face interview. In future studies, I plan to adjust the scheduling of the data collection and analysis procedures to allow for these additional member checks.

Ideas for Future Inquiry and Research

This investigation did illustrate that the high school STEM teachers in this study were using educational technology for the purposes of differentiated instruction; additionally, the activity systems analyses demonstrated the complexity and interconnectedness of all of the CHAT components (e.g., tools, rules, community, division of labor, object, and outcome) and the contradictions and tensions that can arise from their interactions. There are, however, multiple neighboring activity systems that also influenced the activity of each teacher participant. For the purposes of this study, the scope was limited to the activity systems of the teacher participants unless a quaternary contradiction with a neighboring activity system was specifically mentioned or observed during the course of the data collection process.

Further insight could be gained from investigations into the activity systems of members of the teachers' communities, such as the students, administrators, and technology support staff. Administrators, students, and technology coordinators may present differing perspectives that could also help shed light on some of the affordances and challenges of utilizing educational technology to differentiate instruction.

Concluding Thoughts

As the educational climate continues to evolve, with increasing diversity of students in the classroom and improving accessibility to educational technology, it is imperative that educators take proactive steps to learn how to best integrate new technologies to help meet the needs of the individual learners in the classroom. While differentiation strategies are not a novel concept, the application of educational technology may provide teachers with a means to more effectively and efficiently deliver differentiated instruction to their students.

Although few studies have been conducted to examine high school teachers' use of educational technology to differentiate instruction, this research provides evidence that these strategies and activities are occurring in some high school STEM-related classrooms. While the cases presented in this study represent individual teachers from two individual schools, several commonalities were identified during the cross-case analysis. The rich and thick descriptions presented in Chapter 4 set the stage to understand and visualize the components of each teacher participant's activity system, while CHAT served as the framework for analysis of the interconnectedness of these components and how they sometimes conflicted with one another. This allowed me to then focus on each teachers' use of educational technology as it applied to differentiation, providing insight into the affordances and challenges of the teachers' implementation of technology-enhanced differentiated instruction strategies. I am hopeful that the findings of this research may help other educators as they combine the affordances educational technology with cogent pedagogical practices, including differentiated instruction strategies, to maximize learning in the classroom and meet the needs of every student.

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Appendix

Semi-structured Interview Questions

First interview.

The purpose of the first interview was to gather general data about the participant and their professional background, as well as their perspectives on differentiation. These questions were adapted from Maeng (2011).

Research Question Addressed	Interview Question	Related CHAT Components*
General teaching background & professional experience	How did you decide to be a teacher? (Probes: What is your highest level of education? What is the concentration/major? Describe your path to becoming a teacher.)	Subject
	How long have you been teaching, and what grades/subjects have you taught? What are you currently teaching?	Subject
	What grades/subjects appeal to you most? Why?	Subject
	What does "STEM" mean to you? What attracts you to teaching a STEM-related course? When did your initial interest in STEM begin?	Subject (also potentially teacher beliefs/tools)
	What does good teaching look like in a [participants' subject] classroom?	Tools: teacher beliefs, teacher pedagogy, classroom management
	How would you describe your role as a teacher during instruction?	Tools: teacher beliefs, teacher pedagogy

		(also potentially rules, community, and/or division of labor)
	How do you maximize learning in your classroom?	Tools: teacher beliefs, teacher pedagogy, technologies
	How do you know when learning is occurring in your classroom? (Probes: How do you know if students "get it?" How do you decide when to move on to the next concept? What kind of a role do assessments play in your instruction?)	Tools: teacher beliefs, teacher pedagogy, assessments, technologies (also potentially community and rules)
	Describe your students' role during learning. (Probes: Do the students assume more of an active or passive role in their learning? Do they participate in the decision-making process? If so, how & when?)	Division of Labor Community Tools: teacher beliefs, teacher pedagogy
	Are there any things at the school/state/national levels that influence the way you teach? What are some examples of this?	Rules Community
	Describe a typical lesson in your class.	Tools: teacher beliefs, teacher pedagogy, technologies
Differentiation	What is differentiated instruction? How would you define differentiated instruction? Have you had any exposure to differentiated instruction prior to this interview? If so, to what extent and in what form?	Tools: teacher beliefs, teacher pedagogy, technologies

	Describe how a differentiated lesson is different from a traditional lesson. Probe: Describe an example of a differentiated lesson.	Tools: teacher beliefs, teacher pedagogy, technologies
	Tell me about how you differentiate instruction. Probes: Can you describe a time that you differentiated the content of a lesson? Can you describe a lesson in which you differentiated the process of how students learn? Describe a lesson in which you differentiated by readiness. How did it go? Can you describe a time that you differentiated a lesson by interest? Can you describe a lesson in which your students produced a differentiated product? Describe a lesson in which you differentiated by learning profile/preferences. How did it go?	Tools: teacher beliefs, teacher pedagogy, technologies

Second interview.

The purpose of the second set of interview questions was to gather data more specific to the use of educational technology for the purposes of differentiation. Questions for future interviews were formed based on data collected from the initial interviews and classroom observations.

Research Question Addressed	**Interview Question**	**Related CHAT Components***
2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?	How have you used technology to differentiate instruction in your classroom? Probes: What specific strategies and types of hardware and software have you used to differentiate instruction?	Tools: technologies, teacher pedagogy

2a. What specific educational technologies do STEM teachers use to differentiate instruction in their courses?		
2b. What are the affordances of such technologies for differentiation?	What would you consider to be the affordances, or possible uses, of technology in differentiating instruction? Probes: What characteristics or properties of these technologies allow them to be used for differentiation? Have you used technology to differentiate instruction in ways that would otherwise not be possible? If so, how? If not, why?	Tools: technologies, teacher pedagogy, teacher beliefs
2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?	What methods and practices are high school STEM teachers using to differentiate instruction in the classroom?	Rules: teacher-generated goals, school/district and state/national policies and guidelines Tools: technologies, teacher pedagogy, teacher beliefs
1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?	Describe your general perspective or views on using educational technology to differentiate instruction in the classroom.	Tools: teacher pedagogy, teacher beliefs
1. What are high school STEM teachers' beliefs about the use	Which factors influence your use of educational technology to differentiate instruction in the classroom?	Rules: teacher-generated goals, school/district and

of educational technology to differentiate instruction in the classroom?		state/national policies and guidelines Tools: technologies, teacher pedagogy, teacher beliefs Community: colleagues, administrators, support staff
1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom? 2b. What are the affordances of such technologies for differentiation?	From your perspective, what are the benefits of using educational technology to reach diverse learners in the classroom?	Rules: teacher-generated goals Tools: technologies, teacher pedagogy, teacher beliefs
2c. What types challenges do high school STEM teachers face when using educational technology for differentiation?	From your perspective, what are the challenges of using educational technology to reach diverse learners in the classroom? Probe: Are there any obstacles that increase the difficulty of using educational technology for differentiation? If so, what are these obstacles?	Rules: teacher-generated goals, school/district and state/national policies and guidelines Tools: technologies,

		teacher pedagogy, teacher beliefs Community: colleagues, administrators, support staff (also potentially division of labor)

Final (third) interview.

The purpose of the final interview questions was to gather more details on previous statements and observations. Additionally, this interview provided the participants with an opportunity to add to or clarify statements from previous interviews and activities from the previous classroom observations.

Research Question Addressed	Interview Question	Related CHAT Components*
1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom? 2. How do high school STEM teachers use educational technology to	Do you employ technology for formative or summative assessment? If so, how? How do you use that data going forward? How do you determine student grouping during instructional activities? Does educational technology affect these decisions? If so, how? How do you feel your use of educational technology (in general) has changed over the past year? Probe: Has it improved? If so, how/why? What are the pedagogical demands of using educational technology for differentiation in your classroom?	Subject, rules, tools, object, outcome

differentiate instruction in the classroom?		
1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom? 2. How do high school STEM teachers use educational technology to differentiate instruction in the classroom?	How do you feel your use of differentiated instruction (in general) has changed over the past year? Probe: Has it improved? If so, how/why?	Subject, rules, tools, object, outcome
1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?	How do you feel your use of educational technology specifically for differentiated instruction purposes has changed over the past year? Probe: Has it improved? If so, how/why? Over the course of the past year, have your goals related to differentiation changed as a result of your participation in this study? If so, how?	Subject, rules, tools, object, outcome
1. What are high school STEM teachers' beliefs about the use	If you could imagine an educational technology that would help you better differentiate instruction, what would be some characteristics of this technology? (hardware and/or software)	Subject, rules, tools, object, outcome

of educational technology to differentiate instruction in the classroom?		
1. What are high school STEM teachers' beliefs about the use of educational technology to differentiate instruction in the classroom?	What else, beyond technology, would help you better differentiate instruction to promote the learning goals in your classroom? What factors – tools, policies, resources, professional development opportunities - related to the community do you think would help you improve your use of educational technology? …your ability to differentiate instruction? …your use of educational technology for differentiated instruction purposes?	Community, division of labor

Vita

Olivia Ritter is from Knoxville, TN, where she received her undergraduate degree and Master of Science degree in Biochemistry and Cellular and Molecular Biology from the University of Tennessee. She then taught eighth grade Science for four years, after which she began teaching high school Chemistry and Biology courses. In her first year of teaching high school courses, she enrolled in the Theory and Practice in Teacher Education doctor program at the University of Tennessee, specializing in Science Education. As a scholar, her primary research interests are differentiated instruction, educational technology, and STEM education.